SECTION 10

BAT, PSES, NSPS, and BMP FINAL COMPLIANCE COSTS

10.1   Introduction

This section describes EPA's final compliance cost estimates for BAT, PSES, NSPS, and BMPs for mills in the Bleached Papergrade Kraft and Soda subcategory and mills in the Papergrade Sulfite subcategory. EPA cost estimates for the proposed BAT, PSES, and BMPs were presented in the Proposal TDD (1). Following the proposal, EPA collected and analyzed additional data and issued a Notice of Data Availability (Notice) on July 15, 1996 (61 FR 36835). In this notice, EPA presented revised cost estimates for two of the options evaluated at proposal. Thus, the mid-1995 status of each mill served as the "baseline" to estimate the compliance cost to implement BAT, PSES, and BMPs option technologies presented in the July notice. The costs presented in the Notice were based on the estimates provided in the June 18, 1996 version of the BAT and BMP Compliance Cost Estimates Report (2).

EPA estimated final costs of BAT, PSES, and BMPs taking into account comments received on the costs presented in the Notice. In this section, EPA presents the final compliance costs for all mills in each subcategory (direct and indirect dischargers) to complete the process changes that comprise the BAT and PSES model technologies and to implement the BMPs. In addition, several additional analyses, including costs reflecting corporate commitments (Section 10.2.5), costs for two TCF option costs (Section 10.2.6), costs for EPA's Voluntary Advanced Technology Incentives Program (Incentives Program) (Section 10.2.7), and costs for a typical mill to install the technology that forms the basis of NSPS (Section 10.4) are included in this section.

10.1.1   BAT and PSES Cost Estimation

EPA developed the BAT cost model to estimate costs for each mill in the BPK and PS subcategories. For PSES, EPA evaluated the same process change technology options as it evaluated for BAT. EPA determined the same in-plant BAT process changes are appropriate to achieve effective pollutant reductions for preventing "pass through" at a POTW. Therefore, EPA used the same cost model to estimate the costs of PSES and BAT. EPA's estimates include the costs for new, upgraded, or modified process units (i.e., evaporators, recovery boiler, and recausticizing) that are incidentally affected by the implementation of BAT and PSES options.

Using the BAT cost model, EPA estimated costs in two ways: (1) an extrapolation of cost model results for ten mills that represent the 86 bleached papergrade kraft and soda mills covered by the rule and (2) a mill-by mill cost estimate for the 86 mills covered by the rule. EPA estimated costs for BAT/PSES Options A and B for the bleach papergrade kraft and soda subcategory based on the mill-by-mill method, and estimated TCF costs based on the extrapolation of ten mills to represent the 86 mills covered by the rule. For papergrade sulfite mills, EPA used the mill-by-mill method.

10.1.1.1 Preliminary Evaluation of Cost Model

In response to comments on the BAT, PSES, and BMPs regulations proposed in 1993, the cost model used to estimate compliance costs was revised significantly. To ensure the proper function of the revised cost model, it was used to obtain a preliminary, order-of-magnitude estimate of the costs of the revised options. In order to perform this preliminary evaluation, EPA developed 10 technology groups, or "cost groups," to represent the range of baseline pulping and bleaching operations used by BPK mills. The 10 groups, labeled A through K are depicted in Table 10-1. In general, mills in lower groups (i.e., A through D) require the most extensive process technology changes and thus are projected to incur the highest costs to comply with the proposed rule. Mills in the higher groups (i.e., E through K) generally have process technologies already in place equivalent to or better than the BAT options.

EPA classified each BPK mill into a costing group. First, each pulping and bleaching line at every mill was classified as Group A through Group K based on the technologies already in place. If a mill had only one bleach line, the group classification applied to the mill as well as the bleach line. Because a mill may have more than one type of bleach line, assigning a complete mill to a group is more subjective than assigning a single line. For such mills, engineering judgment was used to assign the mill to a cost group that would provide the most reasonable estimate of the cost that the mill would incur to implement each option.

EPA chose 10 model mills, one from each group, to estimate the average cost of compliance for all the mills in a group. The estimated compliance costs for each model mill were extrapolated for the entire technology group by multiplying the model mill's costs by the total annual brown stock production for all mills in that group. After summing the results for all 10 groups, EPA obtained total estimated compliance costs. Results of this preliminary cost model evaluation that were compared to the subsequent mill-by-mill (mid-1995) costs discussed below demonstrated results that were within 30 percent accuracy for capital costs. Therefore, as discussed in Section 10.2.6, model-mill costing was used for estimating compliance costs for the two TCF options EPA considered.

Model mill costing was not performed for PS mills. Because this subcategory consists of only 11 mills, compliance costs for this subcategory were estimated using mill-by-mill costing, as described below (Section 10.1.1.2).

10.1.1.2   Mill-by-Mill Costing

Four information sources were used to determine each mill's status from which mill-by-mill costs were estimated:

> BAT Baseline Database;
> Mill cost estimates from proposal;
> BMPs status file; and
> Recovery boiler questionnaire.

The BAT Baseline Database (3) was the main source of updated information for direct- and indirect-discharging mills for both subcategories. Inputs to the BAT Baseline Database include the 1990 census questionnaire information (and subsequent 1991 and 1992 letter updates); industry comments on the proposed rule; industry-supplied data; site visit reports; sampling episodes; meetings and telephone conversations EPA had with industry, environmental groups, and public; and technical articles and conference proceedings.

Mill-by-mill costing proceeded in Quattro™Pro for Windows. One electronic file, or "millsheet," was created for each mill. Once mill-by-mill costing was completed, the results for BPK and PS mills were compiled using macros (a series of command statements that perform compilation tasks) created in Quattro™Pro for Windows. The macros were used to tally the baseline technology in place at the mills, the estimated compliance costs (capital and operating) for each mill, and the mill technology installations or upgrades necessary to meet a particular cost option's requirements. EPA evaluated total costs, annualized costs, and individual technology costs for each option for each subcategory.

10.1.1.3   Final Mill-by-Mill Costing

EPA made minor revisions to the costs presented in the July 1996 Notice in response to comments. EPA made additional changes to the cost model and corrected mill-specific information to estimate final costs for the BPK and PS subcategories (see Section 10.2.2 and Section 10.3.2).

EPA also created modified versions of the cost model to analyze on a model-mill basis the costs of two TCF options and EPA's Incentives Program. Sections 10.2.6 and 10.2.7 contain a discussion of these analyses, including a comparison of the final mill-by-mill cost estimates of BAT, PSES, and BMPs for all options.

10.1.1.4   Final Compliance Cost Estimates

Since the 1993 proposed rule, AF&PA and other commenters submitted compliance cost estimates for BMPs, effluent limitations guidelines (BPT, BCT, and BAT), and standards (NSPS, PSES, and PSNS) that widely diverged from EPA's compliance cost estimates. A number of factors were responsible for those differing cost estimates, but they were primarily driven by differences in costs for BAT process technologies (e.g., brown stock washing, screen

rooms, oxygen delignification, etc.), costs for upgrading chemical recovery systems (most notably recovery boilers) to accommodate BAT process technologies and BMPs, and costs for BMPs and wastewater treatment system upgrades.

EPA's cost bases for BAT/PSES process technologies and BMPs are described in the BAT Cost Model Support Document (4) and accompanying memorandum, "Memorandum: Costing Revisions Made Since the Publication of July 15, 1996 Notice of Data Availability (61 FR 3687)" (5). EPA believes that it has adequately addressed site-specific factors such as site preparation, piping, power requirements, and overhead costs such as project management, insurance, and taxes in estimating compliance costs for BAT technologies, BMPs, and affected process units (i.e., recovery systems) because the costs are based on mill projects supplied by industry that account for such factors.

EPA continues to disagree with industry claims about the extent to which recovery systems will require upgrades as a result of the options considered for the final rule. This is discussed more fully in the Analysis of Impacts of BAT Options on the Kraft Recovery Cycle (6), and Comment Response Document, Volume I, "Issues Concerning EPA's Estimate of the Effect of BAT Options on Recovery Boilers" (7).

Because EPA is not revising conventional pollutant limitations in the final rule and existing treatment systems are generally believed to be adequately designed to comply with the toxic and nonconventional pollutant limitations promulgated by this rule (assuming BAT/PSES process changes are implemented), mills are no longer expected to incur significant treatment system upgrade costs attributable to this rule. As a result, EPA refined its baseline analysis of the existing spill controls already in place at mills and revised its BMP compliance cost estimates based on cost data provided by industry.

10.2 Compliance Cost Estimates for the Bleached Papergrade Kraft and Soda Subcategory

The derivation of compliance cost estimates for the BPK Subcategory is described in the following sections.

10.2.1 Technology Options

EPA's final analysis of BAT and PSES for the BPK subcategory focused on two ECF technology options identified as Option A and Option B. These two options have nine common elements. Sections 8.2.1.1 and 8.2.1.2 detail the technology elements associated with Options A and B, respectively.

10.2.1.1 Process Technologies Costed

Table 10-2 lists the BAT technologies for which EPA estimated costs for each option. EPA also evaluated the impacts to each incidentally affected process unit (i.e.,

evaporators, recovery boilers, and recausticizing systems) to determine the total costs a mill would incur to implement each option. EPA evaluated process technologies in place as of mid-1995 on a mill-specific basis to determine which mills require costs for new or upgraded process unit(s) as a result of implementing BAT technologies. Because EPA regulations require bleach plant and final effluent monitoring, the costs for monitoring equipment are also included in the estimates.

Kappa number targets used for estimating costs were lower than the kappa numbers used to define Option B (see Section 8.2.1.2). The costing targets reflect the fact that current pulping practice produces softwood at kappa number 30 and hardwood at kappa number 20-25, and that modern OD systems achieve approximately 50 percent delignification. Therefore, for costing, the targets were 15 for softwood and 10 for hardwood because a mill intending to achieve limitations based on OD would likely purchase a modern OD system, which is capable of achieving those targets (even though its performance would exceed the delignification achieved by the OD systems used at mills supplying the data EPA used to represent the performance of Option B).

10.2.1.2 BAT Technology Processes Not Costed

EPA considers the use of precursor-free defoamers as part of current baseline technology used today at BPK mills. Defoamers are mineral oil- or water-based products used to break and inhibit the formation of black liquor surface foam. Unchlorinated dioxin precursors are particularly prevalent in certain mineral oils used in these defoamers, but the precursors can be removed by a process called hydrorefining. As evidenced by the drop in measured TCDD and TCDF discharges from bleaching pulp mills, it became known that the use of either water-based defoamers or defoamers made with precursor-free mineral oils in the brown stock or bleach plant areas substantially reduces the dioxin formed in bleaching. Accordingly, most mills began to employ these types of defoamers (8). Consequently, EPA assumes use of precursor-free defoamers to be part of industry's process baseline. Further, any mill not currently using such defoamers can use them without incurring significant cost.

EPA considers chip quality control part of the BAT technology basis because it is an important component of improving yield, reducing bleaching chemical requirements, and optimizing pulp quality. EPA has in fact found that mills can attain adequate control of chip thickness by either the use of thickness screens or by "upstream" controls such as improving the mill's on-site chip-making processes (i.e., maintaining better tolerances on equipment) and imposing tighter quality control standards on chips delivered by off-site sources. Thus, it is possible for mills to achieve adequate chip size control through low or negligible cost beyond current practices to improve quality and uniformity without the need to purchase chip thickness screens (9). Alternatively, mills with poor chip thickness control may choose to install thickness screens, which will pay for themselves by improving yield and reducing bleaching chemical requirements.

Similarly, EPA considers the use of efficient biological wastewater treatment to be part of baseline technology used today at BPK mills. With the exception of one mill that discharges to territorial waters of the United States, wastewater from all mills in the subcategory is treated by biological wastewater treatment. These treatment systems are typically operated to remove in excess of 90 percent of the influent BOD_5 load (1), and are also capable of substantial reductions in COD and AOX. Therefore, EPA did not estimate costs for improving wastewater treatment systems to this level of efficiency.

In addition, implementation of BAT options typically reduce wastewater treatment load (see Section 11.0). EPA, however, did not calculate the savings in operating costs attributable to reduced wastewater treatment system influent BOD_5 load, such as aerator horsepower and electrical use, in estimating the costs of BAT. EPA assumed that operating cost savings at least offset any capital investments in the treatment system required to achieve the reduction in energy consumption. Where a substantial reduction in effluent flow is realized by the BAT technologies in the mill, minor modifications to the effluent treatment systems may be required so that the mill could take advantage of the energy savings mentioned above. These changes might involve installing partitions or baffles to direct flow of effluent in an aerated stabilization basin, or bypassing part of parallel sets of equipment.

10.2.1.3 Basis for Costing Technology Options that also Incidentally Achieve COD Control

EPA's cost estimates include technologies that capture spent pulping liquors and return them to the recovery process. Recovery of spent pulping liquors also incidentally achieve effective COD control. These technologies include:

> Spent pulping liquor spill control (i.e., BMPs, discussed in 2.4.4);
> Effective brown stock washing; and
> Closed brown stock screening.

EPA estimated the cost impact of returning captured spill material to the recovery process under the promulgated BMP program (see Section 10.2.4.4 for details). While the BMP requirements do not mandate the degree to which captured spill material is recovered, EPA has determined that good engineering practice is to recover the material to the maximum degree possible. Such an approach maximizes the value of recovered chemicals and energy (steam), and minimizes the discharge load to the wastewater treatment system, including the COD load. EPA will develop and promulgate COD limitations and standards in a future rulemaking. These limitations and standards will have the effect of reflecting substantial reductions in COD discharges achieved by BMPs for pulping liquor spills and leaks.

Costs for effective brown stock washing are included in the BAT and PSES cost estimate. This technology is used to produce pulp with little black liquor carry-over and is part of the strategy for reducing AOX and dioxin generation. EPA notes that wastewater from upgraded or new washing systems installed to comply with BAT and PSES limitations may be recycled to

the recovery system. While recovery of the washwater does not enhance a mill's ability to comply with the limitations and standards being promulgated at this time, doing so is considered good, and a common pollution prevention practice. As a result, EPA accounted for any increase in the recovery of black liquor from improved washing in the BAT cost model.

Closed screening was also included in EPA's cost estimate for the BAT and PSES options. EPA determined that closed screening, which may be designed to operate as a washing stage, could be implemented under either Option A or Option B at the same cost at mills that require improved washing instead of additional brown stock washers (the supporting information on cost comparison, although protected as CBI, can be found in Table 1 in DCN 145008 (10)). In addition, closed screening is critical for the efficient operation of oxygen delignification, an Option B BAT element. Use of closed screening lowers the overall waste load on the mill wastewater treatment system, including COD load, and is becoming common industry practice.

In order to determine the appropriate costs for Option A, EPA compared the cost of closed screening plus any additional brown stock washing to the cost of improved brown stock washing only. The results were not clear cut. Although the total capital costs for closed screening were less, the annual operating costs for closed screening were somewhat higher. Implementing closed screening allows the decker to be used as an extra, "free" stage of washing, resulting in lower capital costs at mills that require a washing upgrade. To determine the least cost alternative, EPA compared the pre-tax and post-tax present value of Option A with open screening to Option A with closed screening. In several different scenarios, closed brown stock screening was slightly (1 percent or less) less expensive than open screening. As a result, closed screening was retained as a component of Option A.

10.2.2   Costing Revisions

The following section details changes to the cost estimation methodology made since the proposed regulations in 1993.

10.2.2.1   Costing Revisions as a Result of Comments on the Proposal

In response to comments on the proposed rule and as a result of additional information about the industry collected after proposal, EPA modified several assumptions used in estimating costs. A description of the changes that affected costs are summarized below:

1)   EPA incorporated the costs for BMPs and closed screening into the model. Costs for these elements were estimated separately at proposal, using very limited data. EPA received a substantial amount of new data voluntarily submitted by NCASI on BMPs. EPA also collected the data necessary to determine the capital and operating costs for the technologies and for the combined impacts to the recovery system. As described in Section 10.2.1.3, EPA determined that closed screening, which is standard equipment for water balance at mills operating OD, may be implemented to

essentially act as an additional brown stock washer stage at an equivalent cost at mills that do not use OD (although protected as CBI, this information can be found on Table 1 of DCN 14508 (10)). As a result, the total number of new or upgraded brown stock washers for which EPA estimated final compliance costs is less than the number at proposal.

2)   EPA accounted for evaporator modifications when improved brown stock washing and BMP modifications resulted in additional process wastewater (i.e., hydraulic load) sent to the recovery area, thus increasing the capital and operating costs for mills that at baseline operated this affected process unit at capacity.

3)   EPA accounted for increased heat load to the recovery boiler from additional black liquor recovered by BMPs, screen room closure, and improved brown stock washing (heat load from OD was accounted for at proposal). The cost model was revised to estimate the increased capital cost for mills currently operating recovery boilers at capacity and the operating cost savings for reduced fuel requirements as a result of additional steam generation.

4)   EPA provided an allowance to increase the capacity of the recausticizing system which may require as much as 7 percent increase (refer to Chapter 8 of the Analysis of Impacts of BAT Options on the Kraft Recovery Cycle (6)) due to implementation of OD, if the mill had reported to EPA that they operated their recausticizing system at capacity. EPA determined from the NCASI Recovery Furnace Survey that 20 percent of BPK mills do not have spare capacity. The cost model was revised to estimate additional capital and operating costs associated with a recausticizing system upgrade at these mills.

5)   EPA revised the assumption that certain continuous cooking digesters could be modified to extended cooking and achieve the costing target kappa into bleaching. EPA notes that some mills use certain continuous cooking digesters for purposes other than kappa reduction (e.g., some mills use partial extended cooking to affect pulp quality characteristics). These mills cannot retrofit the digesters to achieve the target kappa number for the purpose of complying with BAT and PSES limitations without loss of yield. As a result, EPA estimated the costs for new OD systems that achieve the costing target kappa number at the affected mills (this revised assumption resulted in the apparent decrease in the baseline number of mills and lines using extended cooking presented in Table 10-7).

6)   EPA adjusted equations used to predict the caustic application rate for modified bleaching using data provided by one commenter. This revision increased caustic demand, which, in turn, increased operating costs.

7)   EPA revised cost curves for most equipment items in accordance with the data collected by voluntarily submitted surveys and comments from industry (see BAT Cost Model Support Document (4)). All cost curves were adjusted for inflation from a 1993 to a 1995 basis, increasing capital costs slightly.

8)   EPA revised estimates of costs for compliance monitoring, energy, wood, and chemicals.

9)   EPA estimated costs a mill would incur to accommodate any increased thermal load to individual recovery boilers by estimating costs for addition of anthraquinone to the pulping digester or oxygen-based black liquor oxidation. EPA assumed that mills would most likely reduce the load on the recovery boiler rather than to increase the capacity of an existing boiler for the incremental increase associated with BAT and BMPs (see Section 6 of the Analysis of Impacts of BAT Options on the Kraft Recovery Cycle (6)). To obtain realistic costs, EPA assumed mills would use the most economically feasible upgrade for reducing thermal load.

10.2.2.2   Costing Revisions as a Result of Comments on the Notice

In response to comments on the July 15, 1996 Notice, EPA corrected mill-specific information and made additional changes to assumptions to estimate final costs. These changes were not major revisions to the model. A description of the changes and the effect on costs are summarized below. For a complete description of the following changes, refer to "Memorandum: Costing Revisions Made Since Publication of July 15,1996 Notice of Data Availability (61 FR 36837)" (5).

1)   EPA corrected errors in the application of climate factor. If mills require installation of peroxide storage facilities, chlorine dioxide storage facilities, or new or greenfield chlorine dioxide generators, the capital costs were revised to include the climate factor (i.e., an allowance for enclosing these facilities in a building in cold climates). The changes to capital costs were minor and varied depending on mill location.

2)   EPA revised the assumption that an increase in chlorine dioxide use of one kkg per day would require cost for a chlorine dioxide generator conversion or installation. Instead, EPA assumed that an increase of one kkg per day would trigger an upgrade to the existing generator (i.e., an allowance for minor generator upgrades), while an increase in chlorine dioxide use of

greater than 20 percent above current capacity would trigger either a generator conversion or installation of a new chlorine dioxide generator, which is a more capital-intensive improvement. EPA revised the assumption because several mills operating large generators are capable of upgrading them to expand capacity at a lower cost than installing a new generator to accommodate the amount of chlorine dioxide necessary for ECF bleaching. This revision decreased the capital cost for several mills.

3) EPA corrected the errors in the unit costs of caustic and hydrogen peroxide that resulted from a unit conversion error (this error carried through the proposal and the notice cost estimates). The correct unit costs for caustic and hydrogen peroxide are $0.29/kg and $0.62/kg, respectively, which are approximately half as much as the erroneous costs of $0.54/kg and $1.15/kg, respectively. Although the chemical costs decreased by approximately one half, the effect on overall operation costs (and, likewise, on individual mill operating costs) was a net increase. The reason for this apparent discrepancy is because both ECF technology options result in less chemical consumption overall; therefore, the Notice estimate of net savings from reduced chemical use when using high chemical costs was unreasonably high. Once the correct, lower chemical costs were used, the chemical cost savings decreased, resulting in an overall slight increase in operating costs. Therefore, compared to the costs presented in the Notice, fewer mills now demonstrate overall operating cost savings. This error particularly affected the Option B operating cost estimate, which still displays significant reduction of chemical reduction compared to Option A because of implementation of OD (e.g., operating costs were erroneously estimated as a $7 million savings at the time of the Notice versus a $2 million cost for final estimates presented in 10.1.4).

4) EPA corrected the double counting of taxes and insurance by adjusting the factor used to calculate the cost of maintenance and repair from 4 percent of capital to 2 percent. Taxes and insurance are accounted for in an additional economic analysis described in Economic Analysis for the National Emissions Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper production; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category—Phase 1 (11). As a result, operating cost estimates presented in this section decreased slightly compared to the cost estimates at the time of the Notice.

5) EPA revised the assumption that all softwood lines with OD in place could operate them to achieve a kappa number less than 20 by providing costs for an upgraded OD system when a mill's baseline kappa number was greater than 19. EPA revised this assumption based on mill data, demonstrating

that mills not currently pulping to an unbleached kappa number of less than 20 are not capable of achieving the promulgated limitations and standards without incurring costs. As a result, several mills received capital cost allowances to upgrade OD systems.

6)   EPA revised the assumptions that all hardwood lines that operate OD to achieve kappa numbers of 11 or 12 would incur an operating cost savings in complying with BAT. Previously, EPA assumed these mills could optimize OD to achieve an unbleached kappa number of 10 without incurring capital costs and receiving operating cost savings. Instead, EPA is now assuming that these mills could continue to operate at their current unbleached pulp kappa number without necessarily experiencing any operating cost savings. EPA revised this assumption because mill data demonstrate that these mills are capable of meeting BAT limitations at kappa numbers of 11 or 12.

10.2.3   Baseline Status

At proposal, EPA evaluated BAT, PSES, and BMPs for 88 mills in the BPK subcategory. Since proposal, the total number of mills in the subcategory has decreased from 88 to 86 because one mill closed and another was reclassified as unbleached kraft. Two other mills informed EPA that they would cease bleached kraft production, rather than invest in any new bleaching technology after promulgation of this rule, opting to produce unbleached kraft pulp. As a result, EPA used the cost model to analyze the costs of BAT, PSES, and BMPs for 84 mills (refer to Section 4). However, for EPA's economic analysis (11), these two mills are included in the subcategory profile because mills that produce kraft pulps are subject to MACT I and MACT II. In EPA's economic analysis, EPA estimated MACT I and MACT II costs for these two mills and assumed that they would not incur BAT, PSES, and BMPs costs to determine the economic achievability of the Cluster Rules.

The baseline status of BPK mills both at the time of proposal and in mid-1995 is shown in Table 10-3. The table presents the number of mills and lines that use certain elements of the BAT options at proposal and mid-1995. The table also lists the associated percentage of the total pulp production of the mills using these technologies at proposal and mid-1995. In general, the number of mills and lines and the production percentages have increased, indicating many mills have incorporated elements of the proposed BAT options in this time period. An exception is the number of mills and lines using extended cooking, which is an artifact of overcounting those lines at proposal (see Section 10.2.2.1). Table 10-3 shows the percentage of ECF production has increased by a factor of five while the percent of production using hypochlorite has been cut in half.

10.2.4   Compliance Cost Estimates

The following section presents the compliance cost estimates used in this rulemaking.

10.2.4.1   Total Capital and Operating Compliance Cost Estimates

After revising the model as described in Section 10.2.2, EPA used mill-by-mill costing to obtain final compliance cost estimates for Option A and Option B. Table 10-4 compares the final compliance costs for Option A and B to the costs of the proposed BAT/PSES option. The cost components reported in this section are engineering estimates of the cost of purchasing and installing equipment and the annual operating and maintenance costs associated with that equipment. Proposal costs have been adjusted from 1993 to 1995 dollars to facilitate comparison.

EPA also calculated the annualized costs of Options A and B to facilitate a preliminary comparison of the options prior to performing the economic impact analysis. All cost estimates in this section are expressed in 1995 dollars. Annualized costs, which were calculated on a "per year" and "per ton" basis, are also shown Table 10-4. EPA estimated engineering annualized costs based on a 13 percent nominal (9 percent real) interest rate over 15 years that accounts for tax/depreciation shield using the following equations:

$$\text{Annualized Cost/yr} = I \times ((C \times \text{Capital Cost}) + (P \times O \times \text{Operating Cost}))$$

where:

I	=	Interest factor = 0.1241
C	=	Capital tax/shield depreciation = 0.792
P	=	Present value for operating and maintenance = 9.823
O	=	Operating and maintenance tax shield = 0.593
Capital cost	=	Final capital compliance cost
Operating cost	=	Final operating compliance cost

$$\frac{\text{Annualized Cost}}{t} \qquad \frac{\text{Annualized Cost/yr}}{t/yr}$$

where:

t/yr = kkg/yr   =   metric tons (kkg) of unbleached pulp produced by BPK subcategory in 1995 = 29,200,000 kkg

Table 10-5 presents the final Option A and Option B capital and operating cost estimates broken down to distinguish between direct- and indirect-discharging mills. Nine BPK mills discharge to a POTW (i.e., discharge indirectly) and are subject to PSES, while 75 direct-discharging BPK mills are subject to BAT. Table 10-6 shows the capital and operating cost

ranges for all 84 mills for which costs were developed and the average cost per mill by option (as mentioned previously, two mills in the subcategory were estimated to incur no BAT, PSES, or BMPs costs).

EPA notes that the engineering cost estimates presented in this section, specifically the operating and maintenance costs and annualized costs, differ slightly from the estimates used to calculate this rule's economic achievability. In EPA's economic analysis, operating and maintenance costs include an additional four percent of capital to account for non-plant overhead costs that are not accounted for in the engineering cost estimates. Annualized costs differ slightly because the variables used to calculate the rules economic achievability are more detailed (11). Capital costs in both analyses are equivalent.

10.2.4.2   Technology Components Costs

Tables 10-7 and 10-8 illustrate the cost breakdown for Options A and B, listing the capital and operating contribution of each costed BAT element and each affected process unit to total capital and operating costs, respectively. Table 10-7 shows the capital cost of Option B is approximately twice that of Option A, while Table 10-8 shows the total operating cost for Option B is a fraction of the Option A costs. The total capital costs presented in Table 10-7 do not match the costs presented in Section 10.2.4.1 because the costs in Table 10-7 do not include regional cost factors. Regional cost factors adjust capital costs to account for a mill's geographical location (i.e., rural locations adjusted for lower cost of capital). These factors were applied to the total mill cost after summing all component capital costs and had the net effect of lowering total subcategory capital compliance costs.

The capital and operating costs for several BAT elements and affected process units differ between Option A and B for several reasons. First, Option B includes extended delignification to reduce kappa number prior to bleaching. This, in turn, decreases the amount of chemical required for bleaching to achieve equivalent brightness; therefore, the capital costs for chlorine dioxide generators and the operating costs for chemical demand are considerably lower. The capital and operating costs for hypochlorite elimination are also lower because the decreased chemical demand for Option B enables some mills to avoid replacing hypochlorite stages with a new D-stage. Second, operating oxygen delignification generates more black liquor, which is sent to the recovery system, leading to increased costs for evaporator and recovery boiler upgrades for Option B. Increased black liquor recovery, however, also leads to additional steam generation which reduces operating costs for some mills by decreasing fuel requirements. Lastly, oxygen delignification also consumes more white liquor, creating increased demand on recausticizing systems; therefore, additional recausticizing upgrade costs are associated for Option B and not Option A.

10.2.4.3   Mill Cost Breakdown

Even mills that use Option B technologies (or better) were estimated to incur some costs to comply with BMPs as well as bleach plant and final effluent monitoring costs (although

protected as CBI, Table II itemizes capital and operating costs for each mill, cost group, and the BPK subcategory as a whole in DCN 14508 (10)).

The estimated capital costs are much higher for some mills than others within the same cost group. Many of these high-cost mills require installation of new chlorine dioxide generators and, for Option B, new oxygen delignification systems, which impact capital costs significantly. But, in almost all cases, high costs are attributable to baseline use of hypochlorite. The installation of new D-towers for the elimination of hypochlorite results in high capital costs to comply with either option compared to other mills in the same cost group, although it reduces operating costs by lowering chemical costs.

For both Option A and Option B, EPA's mill-by-mill costing resulted in some mills incurring a net savings in operating and maintenance costs compared to their current status. Three main reasons are responsible for this net savings:

1)   Bleaching chemical costs are the most influential factor determining whether or not individual mill(s) would achieve a net savings for operating costs. Most mills for which EPA estimated operating cost savings, for either option, are estimated to save significantly on chemical costs compared to their mid-1995 operations. Furthermore, as a result of pre-bleaching lignin reduction, the bleaching chemical requirements are less for Option B than Option A. Hence, the opportunity for savings is greater for Option B.

2)   EPA's mill-by-mill costing resulted in a net decrease in evaporator hydraulic load for some mills. Because improving brown stock washing decreases the hydraulic load on evaporators and implementation of BMPs increases the weak black liquor (includes process wastewater) hydraulic load on evaporators, if the reduction in hydraulic load due to improved brown stock washing is greater than the increase in hydraulic load due to implementation of BMPs, an operating cost savings will occur at the evaporator because less steam is required to evaporate a smaller total volume of weak black liquor.

3)   Improving brown stock washing, closing the screen room, and implementing BMPs increases the black liquor recovered per ton of pulp. Burning the additional recovered black liquor in the recovery boiler generates steam, thereby decreasing the amount of steam the mill must generate using supplemental fuel, a net savings.

10.2.4.4   Costs for BMPs

Rationale for Including BMPs - EPA included costs for BMPs as part of the BAT costs for several reasons. First, a portion of the BAT and BMPs compliance costs are

largely inseparable because improved pulping liquor controls can trigger replacement, upgrade, or modification of process units that are also affected by the BAT limitations (e.g., depending on choices made in implementing BAT and BMPs requirements, a mill may determine that the requirements, either singly or together, result in a need to increase evaporator capacity). Incorporating BMPs costs in the BAT estimate recognizes the degree to which BAT and BMPs compliance decision-making is intertwined at mills.

BMPs Cost Estimate - The output of the cost model is an estimate of the cost of complying with BAT or PSES while complying with BMPs. The associated costs of BMPs were removed from the original cost estimates in order to reassess evaporator upgrade costs and recovery boiler capacity adjustment costs, (i.e., anthraquinone pulping or black-liquor oxidation), if such costs would be necessary to comply with BAT or PSES. The "associated costs" incurred through implementation of BMPs include evaporator upgrade costs due to an increased amount of wastewater to evaporate and higher recovery boiler costs due to capacity adjustments to accommodate the incremental increases in thermal load from the recovered black liquor (see Recovery Impacts Document). After removing the impacts of BMPs, recovery boiler costs that may be necessary for the implementation of BAT technologies (e.g., closed screening, new or improved brown stock washing, and extended delignification (Option B only)) were reassessed. The resulting "BAT\PSES-only" capital and operating cost estimates were subtracted from the original cost model output to estimate the BMPs costs for each mill (Table III lists the BAT\PSES-only; BMPs-only; and BAT, PSES, and BMPs capital and operating cost estimates by mill for each option in DCN 14508 (10)).

The total estimated cost of BMP implementation under Option A is slightly greater than BMP implementation cost under Option B (see Table 10-5). This difference lies in the number of mills that would experience the need for recovery capacity adjustment as a result of the two BAT options. Because Option B includes extended delignification, a greater amount of black liquor (albeit of lower heat content) is sent to recovery as compared to Option A. Of the population of mills that currently operate near the maximum thermal capacity of their recovery boilers, a greater number would require capacity increases under Option B than under Option A. When the cost of BMP implementation is examined as an addition to BAT implementation, the added recovery capacity required by BMP implementation is, in the case of a number of mills under Option B, simply an incremental increase on a capacity adjustment that is already needed. In those cases where BAT implementation, rather than BMP implementation, is the "trigger" for recovery capacity adjustment, the cost burden attributable to BMPs is reduced by economy-of-scale and initial cost considerations. In spite of the fact that equivalent thermal load increases are assumed for BMP application to both BAT options, the result is a somewhat reduced BMP implementation cost for Option B when total costs for the BPK subcategory are calculated. The fact that the difference in the calculated total cost for the two options is small demonstrates that this reduced cost of BMP implementation is confined to just a few mills in the subcategory.

10.2.4.5   Total Number of New, Upgraded, or Modified Pulping and Bleaching Technologies

Table 10-9 shows the number of mills for which EPA costed new, upgraded, or modified BAT technologies and other process units (i.e., evaporators, recovery boilers, and recausticizing systems) that are incidentally affected by each option on at least one fiberline. As described in Section 10.2.3, many mills have implemented elements of the BAT options between proposal and mid-1995. As a result, the total that EPA assumes will be necessary for several of these elements has decreased. Several numbers changed (i.e., extended cooking and brown stock washers) because EPA revised costing assumptions (see Section 10.2.2).

10.2.5   Corporate Commitments to Install BAT Elements

After proposal of BAT and PSES in 1993, a number of pulp mill owners and operators announced plans to install new technologies at their facilities. EPA excluded the incurred costs of process changes that were already implemented as of mid-1995 in the cost estimates used to analyze the economic achievability of the rules. However, EPA included the costs of the announced process changes not underway as of July 1, 1995 in the cost estimates used to analyze the economic achievability of the rule. Although EPA included the costs of the process changes announced but not yet underway as of mid-1995 in its final cost estimates, EPA nevertheless evaluated the impact of these costs in an alternative analysis reflecting announced corporate commitments that were not underway as of mid-1995.

Six corporations announced plans to install new technologies at their facilities after proposal of BAT and PSES in 1993. The announced plans involved a total of 24 mills. The process changes were implemented at 12 of these mills by mid-1995, and the costs for these changes were excluded from EPA's analysis of the economic achievability of this rule. Process changes at the other 12 mills were not underway as of July 1, 1995. The costs anticipated for these 12 mills were included in EPA's economic achievability analysis and were also subject to the alternative analysis described below. Table 10-10 lists the corporations announcing commitments for those 12 mills, the process change planned, the number of mills affected by corporate plans, and the reference that contains the corporation decision.

10.2.5.1   Alternative Analysis Reflecting Corporate Commitments

In its alternative analysis, EPA evaluated the impact of corporate commitments by assuming that mills had incurred the costs of the projects that were announced. EPA, therefore, revised a mill's "baseline" technology status to include corporate decisions to install a technology by the end of 1995 if the commitment was confirmed by a corporate statement. EPA performed this alternative analysis in order to determine whether the lower estimated capital costs and operating costs would change EPA's economic impact projections for Options A and B. EPA found that even under the alternative analysis, EPA's projected economic impacts did not change for the two options (12).

Of the 86 mills in the BPK subcategory, corporate commitments were announced but not underway as of July 1, 1995 for process changes at 12 mills. Under this alternative analysis, these mills were credited for operating the announced equipment to implement either ECF bleaching or oxygen delignification followed by ECF bleaching.

The revised "baseline" status of the entire BPK subcategory reflecting this alternative analysis is shown in Table 10-11. The baseline status during proposal and mid-1995 are included for comparison. Assuming all planned process changes are made, the percentage of ECF production will represent approximately half of the total production in the BPK subcategory by the end of 1995.

10.2.5.2   Option A Commitments - ECF Bleaching

Process changes to operate ECF bleaching were announced for 10 mills that operated at less than 100 percent chlorine dioxide substitution as of mid-1995. Under the alternative analysis, the baseline status of each of the 10 affected mills was modified to credit these mills for using 100 percent chlorine dioxide substitution while ensuring other operating conditions remained equivalent (i.e., equivalent chemical charge during each step of the bleach sequence). Other elements of Option A that were not in operation at the affected mills, such as closed screening room, improved brown stock washing, sufficient peroxide or oxygen use for extraction, or elimination of hypochlorite, were not assumed to be instituted as a result of a corporate-level decision to implement ECF bleaching; therefore, costs for these upgrades were included in the alternative analysis cost estimates.

10.2.5.3   Option B Commitments - Oxygen Delignification and ECF Bleaching

Process changes to operate extended delignification followed by ECF bleaching were announced for two mills that did not operate these technologies as of mid-1995. Under the alternative analysis, the baseline status of the two affected mills was modified to credit these mills for using extended delignification with 100 percent chlorine dioxide substitution while ensuring other operating conditions remained equivalent. This alternative analysis did not assume that other elements of Option B that were not in operation during mid-1995 would be implemented as a result of a corporate commitment to implement oxygen delignification and ECF bleaching (i.e., EPA estimated costs for those other elements to calculate the total alternative analysis compliance costs).

10.2.5.4   Compliance Cost Estimates with Corporate Commitments

Overall, under the alternative analysis, adjusting the baseline of the 12 mills affected by corporate commitments resulted in lower estimated capital and operating compliance costs for each option because these mills were credited for already installing the announced BAT elements. Table 10-12 presents a comparison of the final compliance cost estimates of BAT, PSES, and BMPs (from Section 10.2.4.1) and the alternative analysis costs (although protected as CBI, Table IV lists the corporations announcing commitments, the process change planned, the

specific mills affected by corporate plans, and the reestimated compliance cost of each mill in DCN 14508 (10)).

EPA did not use the alternative analysis cost estimates to determine the economic impacts presented in Economic Analysis for the National Emission Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category—Phase I (11) because the mill-specific baseline data used by EPA reflected technologies in place prior to July 1, 1995. Rather, EPA used the final compliance cost estimates presented in Section 10.2.4.1 to determine the economic impacts of this rule.

10.2.6   Estimated Costs of TCF Bleaching Options

The data available to EPA at promulgation of this rule were insufficient to confirm that TCF processes were technically available for the full range of market products currently served by ECF processes. EPA nevertheless evaluated the costs of retrofitting the U.S. bleached papergrade kraft and soda mills to TCF bleaching to provide perspective on the likelihood of TCF processes being found to be economically achievable when they are shown to be technically available.

10.2.6.1   TCF Options

EPA investigated the costs of two TCF bleach sequences, listed in Table 10-13. TCF bleaching, because it eliminates all use of chlorine-containing compounds, also eliminates the possibility for the formation of TCDD, TCDF, or other chlorinated pollutants. Thus the TCF options do not require the elements of Options A and B that minimize the likelihood of generating TCDD/F during bleaching, i.e., use of dioxin- and furan-precursor free defoamers, and strategies to minimize kappa factor and TCDD- and TCDF-precursors in brown stock pulp. The other common elements of Option A and Option B (adequate chip thickness control, closed brown stock pulp screen room operation, effective brown stock washing, elimination of hypochlorite, oxygen and peroxide enhanced extraction, adequate mixing, and efficient biological wastewater treatment) are necessary for successful operation of a TCF bleach sequence and/or for the control of COD discharges. The TCF bleaching sequences also include medium consistency oxygen delignification. The first TCF bleach sequence, identified in this document as Option C, was based on ozone and peroxide bleaching ($OZE_{op}QPZP$); the second TCF-bleaching sequence, hereafter called Option D, was based primarily on peroxide bleaching (OQPP).

10.2.6.2   TCF Costing Methodology

Compliance costs for TCF Option C and Option D were estimated by using the model-mill costing approach (as described in Section 10.1.1.1). EPA used a modified version of the cost model to estimate the costs for the 10 model mills to implement the two TCF options. The costs for each model mill were extrapolated for the entire group. The sum of all the groups provided total compliance cost estimates.

10.2.6.3   TCF Estimated Capital, Operating, and Annualized Costs

The capital and operating costs of the two TCF options differ significantly. Option C is characterized by high capital costs and low operating costs. Conversely, Option D is less capital cost intensive and more operating cost intensive. For Option C, an expensive capital cost technology (ozone delignification) is offset with a decrease in peroxide consumption, thereby decreasing operating costs. Option D incurs high operating costs resulting from increased peroxide consumption. In general, the same mill would need at least twice as much peroxide for Option D as for Option C.

Table 10-14 compares the costs of the TCF options to the final costs of Option A and Option B (although protected as CBI, Table V lists the model-mill costing estimates of each mill for Option C and D and the mill-by-mill cost estimates of each mill for Option A and B in DCN 14508 (10).

10.2.7   Voluntary Advanced Technology Incentives Program Costing

To encourage mills to implement and develop more environmentally beneficial technologies, EPA established the Voluntary Advanced Technology Incentives Program to afford direct-discharging mills an opportunity to comply with more stringent regulations in return for regulatory- and enforcement-related incentives, as well as public recognition. The technology bases for the stringent limitations established for this multiple-tier program include elements of BAT Option B, other advanced technologies, and not-yet-developed processes and technologies that will challenge the industry in the future. The Technical Support Document for the Voluntary Advanced Technology Incentives Program (13) provides a detailed description of this program, including the methodology used to estimate costs.

10.2.7.1   Description of Tiers

EPA's program establishes three sets of Advanced Technology BAT limitations for the voluntary program. Each successive tier is characterized by decreased pollutant discharge and effluent flow. Like the baseline BAT regulation, mills entering this program may implement any technology or process change to achieve the Advanced Technology BAT limitations; however, for costing purposes, EPA has identified specific technologies for each tier that would assist mills in achieving the limitations. The first tier, Tier I, employs the same technologies proposed for Option B; therefore, the costs for this tier are assumed to equal the estimates for Option B. Tiers II and III limitations may be achieved by implementing advanced technologies and flow reduction measures using either an ECF or TCF bleaching process (see Technical Support Document for the Voluntary Advanced Technology Incentives Program (13)).

10.2.7.2   Case-Study Mill

The cost estimates for this program are based on a case-study mill. This mill represents a typical Group C mill (see Table 10-1) that produces approximately 1,000 UBMT/d of pulp using a $CDE_{op}D$ bleach sequence. The case-study mill is representative of the type of mill that may commit to this program. Mills of this size benefit from the economy of scale associated with implementing advanced technologies (e.g., two-stage oxygen delignification and ozone delignification that are more costly than either Option A or Option B).

10.2.7.3   Compliance Costs for the Voluntary Advanced Technology Incentives Program

Table 10-15 shows the approximate costs for the case-study mill to achieve each incentive tier.   These costs represent maximum estimates since many mills will likely combine elements of the Voluntary Advanced Technology Incentives Program with other modernization projects, thereby reducing actual costs. Since undeveloped technologies and processes may be used in the future to achieve the Advanced Technology BAT limitations, EPA expects these approximate cost projections will be reduced over time. Estimated Option A costs for the case-study mill are included in the table for comparison.

10.3   <u>Compliance Cost Estimates for the Papergrade Sulfite Subcategory</u>

In response to comments received after Proposal, EPA divided the 11 mills in the PS subcategory into three segments:

Segment A: Calcium-, magnesium-, or sodium-based sulfite pulping;

Segment B: Ammonium-based sulfite pulping; and

Segment C: Production of pulp and paper at specialty-grade sulfite mills.

10.3.1   Technology Options

EPA's final analysis of BAT and PSES focused on ECF and TCF technology-based options for three different segments. EPA analyzed one BAT and PSES option for each of the three segments. The BAT option for Segment A (calcium, magnesium, or sodium sulfite) is based on TCF bleaching. The BAT and PSES options for Segment B (ammonium sulfite) and Segment C are based on ECF bleaching. Section 8.2.2 details the technology elements associated with each PS segment.

10.3.1.1 Technology Processes Costed

Table 10-16 lists the process technologies for which EPA estimated costs for each option. EPA also evaluated the costs to upgrade incidentally affected process units (i.e., evaporators for PS mills). For the reasons discussed in Section 10.2.1.2, EPA excluded the costs for the use of precursor-free defoamers. Similarly, EPA considers the use of efficient biological wastewater treatment to be part of baseline technology used today at PS mills. Wastewater from all mills in the subcategory is treated by biological wastewater treatment. These treatment systems are typically operated to remove most of the influent BOD_5 load (see Proposal TDD (1)), and are also capable of substantial reductions in COD and AOX. Therefore, EPA did not include costs for improving wastewater treatment systems to this level of efficiency in its BAT cost estimates.

10.3.2 Cost Model Revisions

EPA used a modified version of the cost model developed for the BPK Subcategory to estimate the costs for the PS mills to implement the BAT and PSES options and BMPs. EPA's proposed BAT and PSES for the PS Subcategory was based on TCF bleaching and oxygen delignification. In response to comments on the proposed rule, EPA eliminated oxygen delignification from the final options. Based on information from PS mills employing TCF bleaching, EPA has determined that oxygen delignification is not necessary for TCF bleaching of papergrade sulfite pulp.

In response to comments on the July 1996 Notice, EPA increased the unit cost of caustic and peroxide (detailed in Section 10.2.2 because this change affected BPK mills as well), leading to increased operating cost estimates for PS mills. In addition, the capital costs for the PS subcategory were recalculated to include regional climate factors for the installation of peroxide storage facilities, chlorine dioxide storage facilities, and new or greenfield chlorine dioxide generators (also detailed in Section 10.2.2).

10.3.3 Compliance Cost Estimates

The following sections detail the results of EPA's compliance cost estimates.

10.3.3.1 Total Costs

EPA used the cost model to estimate BAT compliance costs for each segment with a few exceptions. For one hardwood ammonium sulfite mill, the cost of conversion to TCF bleaching was used to estimate the cost of compliance with the revised BAT/PSES rather than the cost of conversion to ECF bleaching. EPA did so because this mill commented that it could feasibly convert to TCF bleaching without altering its product line. (EPA rejected TCF as a viable BAT option for Segments B and C because it was not shown to provide the full range or products made by all mills in these segments including softwood.) Another hardwood ammonium sulfite mill currently employs TCF bleaching. Mills already operating at TCF were estimated for BMPs

capital costs only. Although protected as CBI, Table VI in DCN 14508 (10) lists the 11 PS mills by segment and the type of bleaching employed at each mill (one PS mill does not employ bleaching). Table 10-17 presents a breakdown of the number of mills costed for each BAT option for each segment.

The cost model was not used to estimate total BAT costs for Segment C. The one mill in this segment provided EPA with an estimate of its cost to convert to ECF bleaching (EPA notes that at the time of promulgation, one Segment A mill prepared business plans to produce specialty-grade pulp; however, EPA estimated its compliance costs as a Segment A mill because that was the mill's status as of mid-1995). EPA reviewed this estimate and determined it was reasonable. All cost information associated with the Segment C mill, including a description and a cost breakdown, is CBI; however, this information is listed in located in Table IX in DCN 14508 (10).

Table 10-18 compares EPA's final BAT costs for all three segments to the estimated costs of the proposed BAT option. EPA estimated that all 11 PS mills will incur costs to comply with BAT, PSES, and BMPs. Proposal costs have been adjusted from 1993 to 1995 dollars to facilitate comparison.

EPA also calculated the annualized costs for the PS subcategory, as discussed in Section 10.2.4.1. Annualized costs, which were calculated on a "per year" and "per ton" basis, are also shown Table 10-18. EPA estimated annualized costs based on a 13 percent nominal (9 percent real) interest rate over 15 years that accounts for tax/depreciation shield using the same equations used to calculate costs for the BPK subcategory (see Section 10.2.4.1) except the total of unbleached pulp production equals 1,280,000 kkg the PS subcategory.

10.3.3.2   Technology Component Costs

EPA estimated capital and operating costs for all mills in the PS subcategory. (Table VII presents the technology component costs and the component costs as a percentage of total costs in DCN 14508 (10)).

10.3.3.3   Mill Cost Breakdown

The final capital and operating costs for each of the 11 to comply with BAT, PSES, and BMPs, although protected as CBI, are listed in Table VIII of DCN 14508 (10).

10.3.3.4   Costs for BMPs

Unlike BPK mills, the BMPs cost estimates for PS mills can be easily separated from the BAT costs. For PS mills, the BAT options had no cost impact on recovery systems. The only estimated recovery system costs result from the impact of BMPs on evaporators. EPA assumed implementation of BMPs does not significantly affect recovery boilers for those mills that operate a recovery boiler. Therefore, no costs for recovery boiler capacity adjustments were

estimated. As a result, estimated cost of implementing BMPs include only the capital and operating costs of BMPs and evaporator upgrades. (The BMPs cost estimates for Segment A and Segment B (without regional factors) and the BMPs cost estimate for Segment C, although protected as CBI, are shown in Tables VIII and IX, respectively, in DCN 14508 (10)).

10.3.3.5   Total Number of New or Upgraded Pulping and Bleaching Technologies

EPA estimated the costs of installing technology options. Table 10-19 shows the number of installations of new or upgraded BAT technologies and affected process units necessary for each PS mills to comply with BAT, PSES, and BMPs for Segment A and Segment B. Segment C is excluded to protect CBI; however, a cost breakdown is located in Table IX in DCN 14508 (10).

10.4   NSPS Compliance Costs

EPA evaluated compliance costs for new sources covered under NSPS limitations. In 40 CFR Part 430.01(j), EPA has set forth a definition of "new source" for the BPK and PS and subcategories. In tailoring a "new source" definition specifically for these subcategories, EPA considered what type of fiber line modifications should be subject to NSPS. A fiber line is a series of operations employed to convert wood or other fibrous raw material into pulp. For the BPK and PS subcategories, the fiber line encompasses pulping, deknotting, brown stock washing, pulp screening, centrifugal cleaning, and multiple bleaching and washing stages. EPA has defined a BPK or PS source as a new source if:

> 1)   It is constructed at a site at which no other source is located (i.e., a greenfield mill).
>
> 2)   It completely replaces an existing source. For example, if a fiber line completely replaces an existing fiber line. This definition *does not* include fiber lines enrolled in the Voluntary Advanced Technology Incentives Program (13) or fiber lines modified to comply with baseline BAT.
>
>   EPA notes that the following changes *do not* cause an existing fiber line to be considered a new source:
>
>   > Upgrades of existing pulping operations;
>   >
>   > Upgrades or replacement of pulp screening and brown stock pulp washing operations;
>   >
>   > Installation of extended cooking and/or oxygen delignification systems or other post-digester, pre-bleaching delignification systems;

> Changes in methods or amounts of bleaching chemical applications;
>
> Changes in the types of bleaching chemicals used;
>
> Installation of new bleaching towers to facilitate replacement of sodium or calcium hypochlorite; and
>
> Installation of new bleached pulp washing systems.

3) It is substantially independent of an existing source at the same site (i.e., if an existing mill builds and operates an entirely new fiber line that supplements the capacity of an existing fiber line).

10.4.1   NSPS Compliance Costs for the BPK Subcategory

EPA analyzed the costs of two NSPS options for the control of toxic and nonconventional pollutants: Option B and a TCF option (the latter is discussed in Section 10.4.1.1). Option A costs are also presented for comparison. EPA estimated NSPS capital and operating compliance costs using a modified version of the cost model. EPA's costs are for the complete replacement of a fiber line at a case study mill from Group C (see Table 10-1) that produces approximately 1000 UBAD kkg/day of fully bleached pulp using two lines. (EPA notes that the compliance costs estimated for this fiber line replacement would be the same for a fiber line built at a greenfield mill.) EPA estimated compliance costs assuming most of the recovery process units (i.e., recovery boilers and evaporators) are already in place and capable of accommodating the pollutant load contributed from NSPS technologies (except for recausticizing upgrades for which costs were estimated to account for the increased oxidized white liquor requirement of OD, which is part of both Option B and the TCF option).

Table 10-20 presents EPA's estimated capital and operating costs. Unlike the situation for retrofitting existing sources, Option B capital costs are very close to Option A capital costs (i.e., \$202 million versus \$201 million) because the capital cost required for installation of oxygen delignification for Option B at new sources is only slightly greater than the capital cost required for a larger (and, thus, more costly) chlorine dioxide generator for Option A. However, the reduced chemical demand for Option B results in lower operating costs and leads to lower overall annualized cost compared to Option A.

For the BPK subcategory, EPA is also promulgating NSPS for the conventional pollutants BOD_5 and TSS based on the performance of a secondary wastewater treatment system as characterized by the average performance of the best 50 percent of the existing mills in the subcategory using the appropriate level of control (see Section 8.7). EPA estimated the increased capital cost required to comply with the promulgated NSPS for Subpart B rather than the old NSPS discharge limitations.   The new BPK subcategory encompasses four old subcategories (former Subparts G, H, I, and P). Table 10-21 compares the old NSPS discharge limitations for two of the former subcategories to the promulgated NSPS BOD_5 discharge limitations. The two

former subparts shown, Subparts I and G, had the lowest and highest BOD$_5$ limitations of the four subparts that EPA combined into the new Subpart B. EPA estimated additional cost of compliance with the promulgated NSPS over the cost of compliance with the former NSPS for Subparts I and G, in order to estimate the range of increased cost the promulgated NSPS would require.

As discussed in Section 11 of this report, compared to Option A, implementation of Option B technology will reduce the discharge of BOD$_5$ from the pulping and bleaching processes. EPA accounted for this BOD$_5$ reduction when estimating the incremental cost of the promulgated NSPS for BOD$_5$.

EPA determined that the incremental capital cost of complying with the selected NSPS for all pollutants (i.e., Option B plus conventional pollutant control) is 0.50 to 2.0 percent greater than the capital cost of a new fiber line using Option A that complies with the previous NSPS limitations for conventional pollutants.

10.4.1.1   TCF Technology as the Basis of NSPS for the BPK Subcategory

While Section 10.2.5 shows that retrofitting TCF technology is much more costly than retrofitting ECF technologies, EPA notes that recent data from the construction of greenfield TCF mills outside the U.S. suggest that the costs of such a fiber line may be less than that of a greenfield ECF fiber line.

Table 10-20 includes the capital and operating costs required for a case-study mill to install a greenfield fiber line using TCF technologies as the basis for minimizing new source toxic and nonconventional pollutants. EPA notes that greenfield TCF fiber lines are less expensive because they:

> Obviate the costs required for chlorine dioxide manufacturing;

> Require less physical space; and

> Use bleaching towers that may be constructed of more inexpensive grades of stainless steel compared to ECF bleaching towers which require more expensive alloys and plastics to resist the corrosive action of chlorine dioxide (and degradation products).

TCF technologies, however, are not demonstrated for the full range of bleached kraft pulp production at this time. As a result, EPA intends to gather additional data to determine whether TCF technologies may be available for the full range of market products subsequent to this rulemaking. EPA will determine whether to propose revisions to NSPS based upon TCF and, if appropriate, flow reduction technologies.

10.4.1.2   NSPS Compliance Costs for PS Subcategory

The technology basis of NSPS for the three segments of the PS subcategory are the same as the model BAT for those segments. At this time, EPA *is not* promulgating NSPS for the control of conventional pollutants. As presented in Section 10.4.1 above, EPA found that for the BPK subcategory the cost of NSPS technology is an insignificant fraction of the capital cost of a new fiber line (i.e., 0.50 to 2.0 percent). Although EPA had no data specific to papergrade sulfite mills with which to estimate the costs of a new fiber line for a PS mill, based on the analysis of NSPS costs for the BPK subcategory, EPA expects that the NSPS costs for a PS fiber line would also be an insignificant fraction of the capital costs.

EPA also notes that typical costs of including NSPS technology at a new source mill are substantially less than the costs of retrofitting existing mills. Moreover, the reduced operating costs for the NSPS option allow firms to recover the capital cost associated with the NSPS technology.

10.5   References

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2.   BAT and BMP Compliance Cost Estimates Report. Report prepared by ERG for EPA. Record Section 23.1.3, DCN 13947, June 18, 1996.

3.   BAT Baseline Database. Data on mill characteristics and operations collected by EPA through the 1990 census questionnaire, subsequent contacts with mills by phone, fax, and site visits. Record Section 21.10, DCN 13590.

4.   BAT Cost Model Support Document. Report prepared by Radian Corporation for EPA. Pulp, Paper, and Paperboard Rulemaking, Record Section 23.1.2, DCN 13953, 1996.

5.   Cartwright, G. Memorandum: Costing Revisions Made Since Publication of July 15, 1996 Notice of Data Availability (61 FR 3687). Prepared by ERG for EPA. Record Section 23.1.2, DCN 14493, 1997.

6.   Analysis of Impacts of BAT Options on the Kraft Recovery Cycle (Recovery Impacts Document). Report prepared by ERG and N. McCubbin for EPA. Record Section 23.1.2, DCN 14490, 1997.

7.   Comment Response Document. EPA, Washington DC, Record Section 30.11, DCN 14497, 1997.

8.   Telephone conversation with Mr. W. Gillespie of NCASI. Record Section 23.1.1, DCN 14651, May 5, 1997.

9.   <u>EPA Site Visit Report</u>. Prepared by Radian Corporation for EPA. Record Section 7.4, DCN 7654.

10.   <u>Classified Appendix for Section 10 of the Supplemental Development Document (Costs)</u>. Prepared by ERG for EPA. Record Section 23.1.3, DCN 14508.

11.   <u>Economic Analysis for the National Emissions Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category - Phase I</u>. Prepared by ERG for EPA. Record Section 30.5, DCN 14649, 1997.

12.   Kaplan, M. <u>Effects of Reductions in Costs from Corporate Commitments</u>. Prepared by ERG for EPA. Record Section 27.4.4, DCN 14375, January 1997.

13.   <u>Technical Support Document for the Voluntary Advanced Technology Incentives Program</u>. EPA, Washington DC, Record Section 22.8, DCN 14488, 1997.

Table 10-1

Baseline Technology Groups for BPK Mills

Group[a]	Number of Mills	Example Bleaching Sequences	EC or OD?[b]	Chlorine Used?	Hypo-chlorite Used?	Percent of ClO$_2$ Used
A	3	CEH [c]	No	Yes	Yes	none on site
B	5	CEHD, CED	No	Yes	Maybe	0 in first stage
C	32	C/DEH, C/DEHDED, C/DED, C/DEDED	No	Yes	Maybe	< 70
D	8	D/CEDED, D/CEopDEpD	No	Yes	Maybe	70 to 100
E	12	DEDED, DEopDD	No	No	No	100
G	9	EC or OD with C/DEDED, D/CEDED	Yes	Yes	Maybe	< 100
H	7	EC or OD with DEDED, DEopDD	Yes	No	No	100
I	3	EC and OD with C/DEDED, D/CEDED	Both	Yes	Maybe	< 100
J	4	EC and OD with DEDED, DEopDD	Both	No	No	100
K	1	TCF[c]	Maybe	No	No	none

[a]Group E = BPK BAT Option A, Group H = BPK BAT Option B. Group F was eliminated because no mills belong to the group.
[b]EC is extended cooking (e.g., MCC, EMCC, RDH, or SuperBatch) and OD is oxygen delignification.
[c]Mills using this bleaching sequence do not usually bleach to full brightness.

Table 10-2

Bleached Papergrade Kraft and Soda Process Technologies Costed

Mid-1995 Costing Effort Option Number	Process Technologies Costed[a]
A	` Improved brown stock washing ` Closed brown stock screening ` Hypochlorite elimination ` Oxygen and peroxide enhanced caustic extraction (Eop) ` 100% chlorine dioxide substitution[b] (ECF bleaching) ` Implementing strategies to minimize kappa factor and brown stock precursors[c]
B	` Improved brown stock washing ` Closed brown stock screening ` Hypochlorite elimination ` Oxygen and peroxide enhanced caustic extraction (Eop) ` 100% Chlorine Dioxide Substitution[b] (ECF bleaching) ` Implementing strategies to minimize kappa factor and brown stock precursors[c] ` Kappa number of 15 for softwood and 10 for hardwood entering the first bleaching stage through addition of oxygen delignification and/or extended cooking[d]

[a]BAT/PSES technology options also include use of TCDD and TCDF precursor free defoamers, adequate chip thickness control, and efficient biological wastewater treatment; however, costs were not included (see Section 10.2.1.2).
[b]The costs for high shear mixing are included in the capital costs for increased chlorine dioxide substitution.
[c]Mills may use many strategies to achieve this technology element. EPA estimates include oxygen and peroxide reinforced extraction; improved brown stock washing; closed screening; and high shear mixing and control, which are technologies integral for implementing strategies for minimizing kappa factor and brown stock precursors.
[d]Option B is defined as extended delignification resulting in a kappa number below 20 for softwood and below 13 for hardwood. Lower targets were used for costing to reflect the capability of modern OD systems (refer to Section 8.2.1.2).

Table 10-3

Baseline Status of Bleached Papergrade Kraft and Soda Mills

	Percent of Total Kraft Production at Proposal (%)	Percent of Total Kraft Production at Mid-1995 (%)	Baseline Estimate at Proposal		Mid-1995[a]
100% Substitution Option A (w/o OD or EC)	NC	17.6	# Mills	NC	14
			# Line	NC	24.5
100% Substitution Option B (w/ OD and/or EC)[b]	NC	15.6	# Mills	NC	14
			# Lines	NC	16.5
Total ECF Production (100% Substitution)[b]	6.6	33.2	# Mills	6	27[c]
			# Lines	9	41
Hypochlorite on Site (on at least one line)	37.2	17.6	# Mills	37	20
Oxygen Delignification Only (OD)[b]	11.7	17.3	# Mills	9	14
			# Lines	13	20
Extended Cooking Only (EC)[d]	17.3	5.2	# Mills	12	6
			# Lines	22	6.75
OD and EC	10.7	9.4	# Mills	8	7
			# Lines	10	8
Total Extended Delignification (OD, EC, or OD and EC)[e]	NC	32.6	# Mills	NC	28
			# Lines	NC	35.75
			Total Mills[f]	87	84

NC = not counted.

[a]Fractions denote the amount of time a technology is used on a swing line.

[b]Includes ozone-ECF production.

[c]Because one mill has a line at Option A and one line at Option B, the number of mills at Option A plus the number of mills at Option B does not equal the total number of mills with ECF production.

[d]As noted in Section 10.2.2, the number of mills and lines using EC was overcounted at proposal.

[e]Includes ozone-ECF and TCF production.

[f]Refer to Section 4 for a description of the subcategory profile (i.e., total number of mills) at proposal and mid-1995.

Table 10-4

Comparison of Bleached Papergrade Kraft and Soda BAT, PSES, and BMPs Compliance Cost Estimates

Cost	BAT, PSES, BMPs, and Closed Screening Cost Estimated at Proposal[a]	Option A (BAT, PSES, and BMPs)	Option B (BAT, PSES, and BMPs)
Capital [$ million]	2,160	966	2,130
Engineering O&M [$ million/yr][b]	10.6	113	2.02
Annualized Cost [$ million/yr]	223	176	211
Annualized Cost [$/UBMT][c]	7.50	6.04	7.22

[a]See discussion of BMP proposal cost estimate in Section 10.2.4.4.

[b]The engineering operating and maintenance costs presented in this table differ from the annual costs presented in EPA's economic analysis (10) because the annual costs include an additional four percent of engineering capital cost to account for non-plant overhead costs.

[c]Using 29.2 million UBMT/yr for Options A and B, which is the mid-1995 total production for 84 BPK mills.

Table 10-5

BAT, PSES, and BMPs Compliance Cost Estimates for Direct and Indirect Discharging BPK Mills

	Option A				Option B			
	Capital [$ million]	O&M [$ million/yr]	Annualized Cost [$/yr]	Annualized Cost [$/t][b]	Capital [$ million]	O&M [$ million/yr]	Annualized Cost [$/yr]	Annualized Cost [$/t][b]
PSES	85.5	4.56	137.6	4.71	255	(7.87)	173	5.92
BAT	697	79.3			1,690	(18.1)		
BMPs[a] - direct discharging mills	162	26.9	38.9	1.33	159	26.0	38.0	1.30
BMPs[a] - indirect discharging mills	21.1	2.05			21.2	2.0		
Total[c]	966	113	176	6.04	2,130	2.02	211	7.22

( ) Represents cost savings.
[a]BMPs cost estimates for Option A and Option B differ. Refer to Section 10.2.4.4 for explanation.
[b]Using 29.2 million UBMT/yr for Options A and B, which is the total mid-1995 production for the BPK Subcategory.
[c]Total may not equal sum of column costs due to rounding.

Table 10-6

Range of Estimated BAT, PSES, and BMPs Costs for the 84 Bleached Kraft Mills

	Option A		Option B	
	Capital [$ million]	**O&M [$ million/yr]**	**Capital [$ million]**	**O&M [$ million/yr]**
Range ($/mill)	0.380 to 67.7	(2.75) to 8.31	0.380 to 95.8	(6.08) to 6.70
Total Cost	966	113	2,130	2.02
Average Cost Per Mill	11.5	1.35	25.3	0.02

( ) Represents cost savings.

Table 10-7

Component Capital Costs as Percentage of Total Capital Cost for the Bleached Papergrade Kraft and Soda Mills

Capital Cost Component	Total Capital Cost for Component [$]		Percent of Overall Capital Cost	
	Option A	Option B	Option A	Option B
Kappa Reduction (OD/EC)	NA	1,514,011,241	NA	61.9
BMPs[a]	151,230,000	151,230,000	13.6	6.2
Recovery Boiler	8,688,694	10,638,969	0.8	0.4
Evaporator	53,588,584	53,588,584	4.8	2.2
Closed Screening/Brown Stock Washing	199,812,266	199,812,266	17.9	8.2
ClO$_2$ Generator	429,048,659	262,360,284	38.5	10.7
Adding Eop	35,765,522	35,765,522	3.2	1.5
Adding D-Towers (Eliminate Hypochlorite)	220,220,635	164,556,880	19.8	6.7
Recausticizing	NA	37,824,295	NA	1.5
Monitoring	16,008,404	16,008,404	1.4	0.7
Total Capital Cost[b]	1,114,362,762	2,445,796,444	100	100

NA = Not applicable to option.

[a]See Section 10.2.4.4 for BMPs cost estimate discussion. The BMPs line item costs only reflect capital and operating costs for implementing spill prevention and control systems. The cost impact on the recovery boiler or the evaporator set from implementing BMPs is included in the line items for those areas.

[b]Because the regional cost factor is not applied at the component cost level, to estimate component costs as a percentage of total cost the total capital cost estimates are shown without the regional cost factor. As a result, the total capital cost estimates shown above appear higher than the BAT, PSES, and BMPs final compliance cost estimates shown throughout this section. In addition, totals may not equal the sum of component costs due to rounding.

Table 10-8

Component Operating Costs as Percentage of Total Operating Cost for the Bleached Papergrade Kraft and Soda Mills

| Operating Cost Component | Total Operating Cost Component [$/yr] | | | | Percent of Overall Operating Cost (%) | | | |
| | Option A | | Option B | | Option A | | Option B | |
	Cost	Savings	Cost	Savings	Cost	Savings	Cost	Savings
Kappa Reduction (OD/EC)	NA	NA	$95,782,769	---	NA	NA	65.2	---
BMPs	$6,384,600	---	$6,384,600	---	5.3	---	4.3	---
Recovery Boiler	---	$8,461,087	---	$9,702,373	---	100.0	---	6.7
Evaporator	$9,416,761	---	$9,416,761	---	7.8	---	6.4	---
Closed Screening/Brown Stock Washing	$2,021,791	---	$2,021,791	---	1.7	---	1.4	---
ClO$_2$ Generator	$10,538,157	---	$7,204,390	---	8.7	---	4.9	---
Adding Eop	$1,822,350	---	$1,851,941	---	1.5	---	1.3	---
Adding D-Towers (Eliminate Hypochlorite)	$4,764,793	---	$3,482,789	---	3.9	---	2.4	---
Recausticizing	NA	NA	$756,486	---	0.0	---	0.5	---
Monitoring (Bleach Plant and Final Effluent)	$9,421,664	---	$9,421,664	---	7.8	---	6.4	---
Additional Chemical Cost Over Base	$72,059,428	---	---	$135,243,178	59.4	---	---	93.3
Supervision and Technical Support	$4,828,048	---	$10,645,282	---	4.0	---	7.2	---

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Table 10-8 (Continued)

Operating Cost Component	Total Operating Cost Component [$/yr]				Percent of Overall Operating Cost (%)			
	Option A		Option B		Option A		Option B	
	Cost	Savings	Cost	Savings	Cost	Savings	Cost	Savings
Subtotal for Operating Costs	$121,257,592	---	$146,968,473	---	100	---	100	---
Subtotal for Operating Savings	---	$8,461,087	---	$144,945,551	---	100	---	100
Total Operating Cost and Percentages[b]	$112,796,505		$2,022,922		100.0	100.0	100.0	100.0

NA = Not applicable for the option.

[a]See Section 10.2.4.4 for BMPs cost estimate discussion. The BMPs line item costs only reflect capital and operating costs for implementing spill prevention and control systems. The cost impact on the recovery boiler or the evaporator from implementing BMPs is included in the line items for those areas.

[b]Totals may not equal the sum of component costs due to rounding.

Table 10-9

Bleached Papergrade Kraft and Soda Mill Technology Upgrades Costed

		Proposal[a] (number costed)	Final (number costed)
Screen Room Upgrades (Number of Mills)			
Option A		CS	40
Option B		CS	40
Brown Stock Washer Upgrades (Number of Mills)			
Option A	Add'l Stages	37	22
	New Washers	5	1
Option B	Add'l Stages	37	22
	New Washers	5	1
Evaporator Upgrades (Number of Mills)			
Option A		NC	20
Option B		NC	20
Chlorine Dioxide Generator Upgrades (Number of Mills)			
Option A	Greenfield	6	5
	New	56	40
	Upgrade	NC	8
	Conversion	18	5
Option B	Greenfield	6	5
	New	48	28
	Upgrade	NC	3
	Conversion	17	4
Oxygen Delignification Installations			
Option A	# Mills	NA	NA
	# Lines	NA	NA
Option B	# Mills	56	65
	# Lines	96	96
Extended Cooking Installations (All Retrofits)			
Option A	# Mills	NA	NA
	# Lines	NA	NA
Option B	# Mills	3	3
	# Lines	3	3

Table 10-9 (Continued)

		Proposal[a] (number costed)	Final (number costed)
Recovery Boiler Capacity Adjustments (Number of Mills)[b]			
Option A	Anthraquinone	0	9
	O_2 Black Liquor Oxid.	NC	13
	Upgrade	0	1
	Total Number of Capacity Adjustments	0	23
Option B	Anthraquinone	55	10
	O_2 Black Liquor Oxid.	NC	16
	Upgrade	55	1
	Total Number of Capacity Adjustments	55	27
Mills Adding Eop (Number of Mills for at Least One Line)			
Option A		64	49
Option B		64	49
Mills Adding New D-Stage to Eliminate Hypochlorite Bleaching (Number of Mills)			
Option A		32	12
Option B		27	9
Recausticizing Upgrades (Number of Mills)			
Option A		NA	NA
Option B		NC	15

[a]Proposal Option 2A = Final Option A, Proposal Option 3A or 4 = Final Option B.
[b]EPA revised costing methodology after proposal for estimating recovery boiler costs (see BAT Cost Model Support Document) based on data presented in RID.
CS = costed separately. Model included closed screening for mid-1995 analysis. Refer to Section 10.2.2 for affect on brown stock washer estimate.
NA = not applicable for option
NC = not costed at proposal or notice. Refer to Section 10.2.2 for explanation.

Table 10-10

Corporations Announcing Commitments to Upgrade Process Technologies to Include BAT Elements After July 1, 1995

Corporation	Number of Affected Mills	Announced Commitment	Reference
International Paper	8	100% ClO_2	DCN 14326 Section 23.1.1
Champion International	1	OD/100% ClO_2	DCN 13632 Section 23.1.1
Georgia-Pacific	1	OD/100% ClO_2	DCN 13102 Section 23.1.1
Westvaco	1	100% ClO_2	DCN 13600 Section 23.1.1
Willamette Industries	1	100% ClO_2	DCN 13641 Section 23.1.1

Table 10-11

Baseline Status of Bleached Papergrade Kraft and Soda Mills Including Adjustment for Corporate Commitments to Install BAT Elements

	Percent of Production (%)			Baseline Estimate at Proposal		Mid-1995[a]	Mid-1995 w/ Commitments[a]
	At Proposal	Mid-1995	After Commitments				
100% Substitution Option A (w/o OD or EC)	NC	17.6	25.5	# Mills	NC	14	22
				# Line	NC	24.5	38.75
100% Substitution Option B (w/ OD and/or EC)[b]	NC	15.6	21.4	# Mills	NC	14	17
				# Lines	NC	16.5	22.5
Total ECF Production (100% Substitution)[b]	6.6	33.2	46.9	# Mills	6	27[c]	38
				# Lines	9	41	61
Hypochlorite on Site (on at least one line)	37.2	17.6	17.6	# Mills	37	20	20
Oxygen Delignification Only (OD)	11.7	17.3	18.8	# Mills	9	14	15
				# Lines	13	20	21
Extended Cooking Only (EC)[d]	17.3	5.2	5.2	# Mills	12	6	6
				# Lines	22	6.75	6.75
OD and EC	10.7	9.4	9.4	# Mills	8	7	7
				# Lines	10	8	8
Total Extended Delignification (OD, EC, or OD and EC)[e]	NC	32.6	34.1	# Mills	NC	28	29
				# Lines	NC	35.75	36.75
				Total Mills[f]	87	84	84

NC = Not counted.

[a]Fractions denote the amount of time a technology is used on a swing line.

[b]This includes ozone-ECF bleaching mill.

[c]Because one mill has a line at Option A and one line at Option B, the number of mills at Option A plus the number of mills at Option B does not equal the total number of mills with ECF production.

[d]As noted in Section 10.2.2, the number of mills and lines using EC was overcounted at proposal.

[e]This includes ozone-ECF and TCF production.

[f]Refer to Section 4 for a description of the subcategory profile (i.e., total number of mills) at proposal and mid-1995.

Table 10-12

Bleached Papergrade Kraft and Soda Total BAT, PSES, and BMPs Cost Estimates with Process Upgrades Announced but not Underway by Mid-1995

	Option A				Option B			
	Capital [$ million]	O&M [$ million/yr]	Annualized Cost [$/yr]	Annualized Cost [$/t][a]	Capital [$ million]	O&M [$ million/yr]	Annualized Cost [$/yr]	Annualized Cost [$/t][a]
Mid-1995 Baseline	966	113	176	6.04	2,130	2.02	210	7.22
Baseline Adjusted for Alternative Analysis	882	74.1	140	4.80	2,050	(31.4)	179	6.14

( ) Represents cost savings.
[a]Using 29.2 million UBMT per year for Options A and B, which is the mid-1995 total production for the Bleached Papergrade Kraft and Soda Subcategory.

Table 10-13

TCF Process Technologies Costed

TCF Option	Process Technologies Costed
Ozone-based (Option C)	` Improved brown stock washing ` Closed brown stock screening ` Kappa number of 10 for softwood and 6 for hardwood entering the first bleaching stage though oxygen delignification **AND** anthraquinone addition to the digester ` Ozone bleaching (delignification) ` Oxygen and peroxide enhanced caustic extraction ` Substitution of peroxide bleaching for all chlorinated bleaching compounds (TCF bleaching)[a] ` Chelant addition ` Bleach Sequence: OZEopQPZP
Peroxide-based (Option D)	` Improved brown stock washing ` Closed brown stock screening ` Kappa number of 10 for softwood and 6 for hardwood entering the first bleaching stage though addition of oxygen delignification **AND** anthraquinone addition to the digester ` Substitution of peroxide bleaching for all chlorinated bleaching compounds (TCF bleaching)[a] ` Chelant addition ` Bleach sequence: OQPP

[a]The costs for mixing are included in the capital costs for totally free chlorine bleaching.

Table 10-14

Comparison of BAT and PSES Option Costs for the Bleached Papergrade Kraft and Soda Subcategory

	Option A[a] (ECF)	Option B[a] (OD-ECF)	Option C[b] (Ozone-TCF)	Option D[b] (Peroxide-TCF)
Capital Cost [$ million]	966	2,130	5,630	3,090
Operating Costs [$ million/yr]	113	2.02	849	660
Annualized Cost [$ million/yr]	176	211	1,170	780
Annualized Cost [$/UBMT]	6.04	7.22	40.0	26.7

[a]Estimated using mill-by-mill costing approach.
[b]Estimated using the model-mill costing approach detailed in Section 10.1.1.1.

Table 10-15

Case Study Mill Incentive Tier Costs

	Option A	Tier I	Tier II	Tier III
TCF Alternative				
Capital Cost [$ million]	NA	NA	88.0	108
O&M [$ million/yr]	NA	NA	0.56	2.65
Annualized Cost [$/UBMT]	NA	NA	23.9	33.8
ECF Alternative				
Capital Cost [$ million]	18.5	44.0	51.6	70.9
O&M [$ million/yr]	3.34	0.876	(0.682)	(0.134)
Annualized Cost [$/UBMT]	11.5	13.4	12.4	19.1

( ) Represents a savings.

NA = Not applicable because option/tier is not based on this type of bleaching process. However, EPA expects that mills employing a TCF bleaching process will be able to achieve at least the Tier I Advanced Technology BAT limitation for AOX and may be able to achieve the other ultimate Tier I limitations as well.

Table 10-16

Papergrade Sulfite Technology Process Technologies Costed

Segment	Bleaching Option	Process Technologies Costed
A - Calcium-, Magnesium-, or Sodium-Based Sulfite Pulping	TCF	` Totally chlorine free bleaching (bleaching with peroxide) ` Elimination of hypochlorite ` Oxygen and peroxide enhanced extraction ` Improved pulp cleaning
B - Ammonium-Based Sulfite Pulping	ECF	` 100% chlorine dioxide substitution (ECF bleaching)[a] ` Hypochlorite elimination ` Peroxide enhanced extraction
C - Specialty-Grade Sulfite Pulping	ECF	` 100% chlorine dioxide substitution (ECF bleaching)[a] ` Hypochlorite elimination ` Oxygen and peroxide enhanced extraction

[a]The costs for high shear mixing are included in the capital costs for increased chlorine dioxide substitution.

Table 10-17

ECF Versus TCF Costing for the Papergrade Sulfite Mills

Segment A - Calcium, Magnesium, or Sodium Sulfite BAT Option = TCF	
Total Mills	6[a]
Number of mills costed for conversion to TCF	4
Number of mills currently bleaching at TCF (estimated costs for BMPs, evaporator, monitoring)	1
Number of mills producing papergrade sulfite pulp, without bleaching (estimated costs for BMPs, monitoring)	1
Segment B - Ammonium Sulfite BAT Option = ECF	
Total mills	4[b]
Number of mills costed for conversion to ECF	1
Number of mills costed for conversion to TCF (one mill commented they could feasibly convert to TCF bleaching with lower cost)	1
Number of mills currently bleaching at or committed to ECF (estimated costs for BMPs, monitoring)	1
Number of mills currently bleaching at TCF (estimated costs for BMPs, monitoring)	1
Segment C BAT Option = ECF	
Total mills	1
Number of mills costed for conversion to ECF	1

[a]One mill currently producing papergrade sulfite pulp has prepared business plans to produce specialty-grade pulp but was costed as a Segment A mill because that was the mill's status as of mid-1995.
[b]One mill recently ceased papergrade sulfite operations; however, EPA includes the costs of this mill because as of mid-1995 the mill was producing papergrade sulfite pulp. EPA also estimated the costs for the nine direct discharging PS mills that are subject to BAT, which are CBI; however, this information is listed in Table VIII in DCN 14508 (8)).

Table 10-18

Total BAT, PSES, and BMPs Papergrade Sulfite Compliance Cost Estimates (All Segments)

	BAT, PSES, and BMPs Compliance Cost Estimates			
	Capital [$ million]	O&M [$ million/yr]	Annualized Cost [$ million/yr]	Annualized Cost [$/t]
Cost Estimated at Proposal	88.3	17.8	21.5	19.06
Cost Estimates for Mid-1995[a]	73.8	4.59	10.6	8.24

[a]Although a cost breakdown for each segment is not presented because this information is CBI, this information is listed on Table VIII in DCN 14508 (8).

Table 10-19

Papergrade Sulfite Technology Upgrades

	Segment A (Calcium, magnesium, or sodium sulfite) BAT Option = TCF	Segment B (Ammonium sulfite) BAT Option = ECF	Segment C (Specialty Grade)
Installation of Final P-Stage	4	1	ND
Chlorine Dioxide Generator Upgrades	0	1	ND
Add New D-Tower (Eliminate Hypochlorite)	0	1	ND
Add Eop	3	2	ND
Evaporator Upgrades	3	3	ND

ND = Not disclosed to protect confidential business information. The technologies for the Segment C mill are identified in Table IX in DCN 14508 (8).

Note: Technology upgrades included in proposal cost estimates are not presented because the proposed option is not comparable to the revised options.

Table 10-20

NSPS Compliance Costs

Toxic and Conventional Pollutant Control			
	Option A	**Option B**	**TCF**
Typical Bleach Sequence	DE$_{op}$DnD	OODE$_{op}$D	OO(Q$_w$)OP(ZQ)(PO)
Capital Costs ($ million)			
Unbleached Pulp Mill			
New Continuous Digester	53.0	53.0	53.0
New Brown Stock Washing Line	19.4	19.4	19.4
New Closed Screening System	5.94	5.94	5.94
Building and Infrastructure	6.00	6.00	6.00
Bleach Plant			
OD System	--	29.4	29.4
New D-Stage Tower and Washer	15.5	15.5	--
New Eop Stage with Washer	11.3	11.3	--
New D-Stage Tower and Washer	15.5	15.5	--
New E2 Stage with Washer	10.2	--	--
New D-Stage Tower and Washer	15.5	--	--
Chelant Stage with Press Washer	--	--	4.77
Pressurized PO stage with Washer	--	--	9.55
High Consistency Ozone System	--	--	25.7
Pressurized PO Stage with Washer	--	--	9.55
Chelant Supply System	--	--	0.200
Peroxide Unloading and Storage	0.125	0.125	0.125
Monitoring	0.124	0.124	--
Buildings	12.0	12.0	6.00
Miscellaneous Infrastructure	13.6	14.4	15.9
Greenfield ClO2 Generator	21.6	16.2	--
ClO2 Storage	1.47	1.06	--
Upgrade Recausticizing	--	3.10	4.65
Total Capital Cost	201	202	190
Operating Costs			
Annualized Costs ($/t of pulp)	112	102	96.9
Annual Cost ($/year)	39,200,000	35,600,000	33,900,000
Conventional Pollutant Control ($)			
Capital Cost ($)	162,000 to 3,400,000		

Table 10-21

NSPS Limitations

NSPS	Former NSPS Limitations (kg/kkg)		Promulgated NSPS (kg/kkg)	
Conventional Pollutants	**BOD5**	**TSS**	**BOD5**	**TSS**
Old Subpart I - Fine Bleached Kraft[a]	2.22	---	---	---
Old Subpart G- Market Bleached Kraft[a]	4.02	---	---	---
New Subpart B - Bleached Papergrade Kraft	---	---	1.73	---

[a]These subcategories were distinct in the previous rulemaking; however, all previous bleached kraft subcategories have been reorganized in one subcategory, Subpart B, by this rulemaking. These two former subcategories represent the range of limitations that are being revised by the promulgation of the limitation for Subpart B in this rulemaking.

SECTION 11

NON-WATER QUALITY ENVIRONMENTAL IMPACTS

11.1   Impacts of BAT, PSES, and BMPs on the Bleached Papergrade Kraft and Soda Subcategory

This section describes EPA` s estimate of the water quality environmental impacts of the final options considered for effluent limitations guidelines and standards for the bleached papergrade kraft and soda subcategory of the pulp and paper industry. The non-water quality environmental impacts for the incentives tiers are presented in detail in the Technical Support Document for the Voluntary Advanced Technology Incentives Program (1). Major impacts are summarized in Table 11-1 and discussed further below.

The estimated effects of BAT, PSES, and BMPs on mill effluents, atmospheric discharges, and energy consumption discussed in this section are based on the assumption that all mills adopt the Option A or Option B process technologies described in Sections 8.2.1.1 and 8.2.1.2, respectively. This section also presents EPA's analysis of non-water quality environmental impacts for TCF bleaching processes.

11.1.1   Summary of Impacts on Wood Consumption

As discussed in detail in Section 11.2, EPA estimates wood consumption could be reduced by up to 0.3 percent by the implementation of either Option A or Option B and BMPs. The reduction in wood consumption is a result of the reduction in losses of useful fiber associated with the recovery of spills (BMPs) and improvements in washing and screening of pulp.

11.1.2   Summary of Impacts on Wastewater Flow, BOD_5, and Solid Waste Generation

As discussed in detail in Section 11.3, the BAT, PSES, and BMP options analyzed by EPA will result in progressive reductions in process wastewater flows and pollutant loadings. Generally, the reductions for Option B are greater than Option A.

The average US bleached kraft and soda mill discharges approximately 95 m^3/kkg of treated effluent. EPA estimated that Option A could result in process wastewater flow reductions ranging from 10 to 50 m^3/kkg. The greater reductions would be realized in mills presently discharging the highest flows. Option B would result in an additional process wastewater reduction of up to 15 m^3/kkg at mills with the highest effluent flows. See Section 11.3 for a detailed discussion.

EPA also estimates that raw (untreated) BOD_5 loads would be reduced by 21 percent through implementation of Option A, and further (31 percent) by Option B. This

reduction would have only a modest effect on treated effluent discharges, but would reduce energy consumption and solid waste generation. Energy equivalent to approximately 680,000 bbls oil would be saved in the waste treatment plants by Option A and 1,000,000 bbls oil by Option B (see Section 11.4.2.2).

EPA estimates that the reduction in BOD_5 load to activated sludge wastewater treatment plants (WWTP) will result in a 2 percent reduction in the generation of secondary wastewater treatment sludge for Option A. Option B will result in a 3 percent reduction.

11.1.3   Summary of Impacts on Energy Consumption

Section 11.4 of this report provides the results of EPA`s detailed analysis of the energy requirements of BMPs combined with Option A and Option B. As detailed in Section 11.4, bleached kraft mills generate a significant proportion of the energy necessary to operate pulping and bleaching processes through the chemical recovery process. Implementation of Option A or Option B in combination with BMPs would increase recovery of organic material with a resulting increase in energy generated at the mill.

The most useful measures of kraft mill energy performance are the quantity of energy purchased, including energy associated with off-site manufacturing of bleaching chemicals, and energy needed for mill effluent treatment. Implementing Option A would increase purchased energy consumption by approximately one percent, while implementing Option B would reduce it by one percent.

11.1.4   Summary of Impacts on Atmospheric Emissions

Section 11.5 of this report provides the results of EPA`s detailed analysis of the air pollution impacts of Option A and Option B. The process changes related to these options decrease the emissions of some HAPs but have little impact on others. Overall, the emission of total HAPs from the sources controlled by MACT I decrease by 7 percent compared to baseline for BAT Option A.

Implementation of Option A may marginally increase the emission of HAPs from the recovery furnace by up to 1.5 percent, while Option B may result in a marginal increase of up to about 2.2 percent. However, capacity adjustments and upgrades[1] to recovery boilers as part of mill modernization programs could also result in reduction of emissions below current levels.

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[1]Capacity adjustments and upgrades that would generally reduce emissions of some or most pollutants include raising the solids concentration of the black liquor fired, improved turbulence and control of air system, improved boiler instrumentation, automatic port rodding, extraction of lignin from black liquor, heat treatment of black liquor, and improvement of pulping yield. However, EPA estimates that only one recovery boiler would require an air system and control upgrade in order to achieve the effluent limitations guidelines and standards promulgated for Subpart B. See Analysis of Impacts of BAT Options on the Kraft Recovery Cycle (DCN 14490) (2).

As explained in Section 11.5.4, the pollution prevention measures implemented at mills in response to BAT and PSES would have no direct effect on emissions of carbon dioxide, the greenhouse gas of concern in this analysis. However, emissions of carbon dioxide will change approximately in proportion to the changes in energy consumption mentioned above due to the secondary effects of modifying the quantity of fossil fuel burned to serve the pulp industry. EPA concludes that the increased CO_2 emission attributable to Option A pose no unacceptable non-water quality environmental impact.

Sections 11.5.5 and 11.5.6 present EPA`s analysis of carbon monoxide emissions related to effluent limitations guidelines. Emissions of carbon monoxide will increase from bleach plants (1,500 kkg/yr over 1995 status) and from combustion of black liquor solids will increase (1,440 kkg/yr over 1995 status, for a total increase of 2,940 kkg/yr over 1995 status) if Option A technologies are implemented. If all mills implement Option B technologies, the increase in carbon monoxide emissions would be approximately 240 kkg/yr and 2,120 kkg/yr over 1995 status, respectively.

11.2 Wood Consumption

This section describes the effect this rulemaking will have on wood consumption at pulp mills.

11.2.1 BAT and PSES Option A

EPA analyzed the impact of Option A on wood consumption. The effluent flow from a typical open screening system ranges from 10 to 25 m^3/kkg pulp, as discussed below in Section 11.3. This screen room effluent normally contains 20 to 50 mg/l wood fibers, in addition to whatever screen rejects are discharged with the water. The quantity of fiber lost continuously will therefore range from 0.2 to 1.25 kg/kkg pulp or approximately 0.1 percent of production. When converting a screen room to closed operation, this loss to effluent discharge is eliminated by capture and recycle to the brown stock washers.

In any mill, incidents occur from time to time that result in all of the production being dumped on the floor for a short period. The most common reason is an overflow of a vacuum drum washer, but any pipe can burst or tank overflow. Operators react quickly to such significant malfunctions, but 5 to 30 minutes is often necessary to stop the discharge. Assuming a typical tank overflow lasts 15 minutes, one percent of one day`s production would be lost. Traditionally, the pulp and associated black liquor lost in this way is washed down the sewer, and ultimately lost from the process. With the implementation of BMPs, however, most of the material which escapes the production equipment will be recovered. Sufficient data are not available to quantify such losses, but losses of 2 kg/kkg would not be unusual, so it can be assumed that implementation of BMPs will result in a small improvement in wood yield due to recovery of this pulp.

Thus, mills with open screening at baseline that implement Option A technology (including closing the screen room) after the implementation of BMPs, would experience at least 0.1 percent reduction in wood consumption and more likely up to 0.3 percent while maintaining current production.

11.2.2 Option B

EPA estimated that Option B would also result in up to 0.3 percent reduction in baseline wood consumption. Option B differs from Option A only by the inclusion of extended delignification (oxygen delignification or extended cooking). EPA concluded that the installation of oxygen delignification without changing pulping conditions (EPA Option B) would not incrementally affect overall process yield when compared to Option A (3).

11.3 Effluents and Solid Waste

Implementation of BAT, PSES, and BMPs will reduce effluent flow, as well as the load of organic substances and suspended solids discharged to the mills` effluent treatment systems. The reduction in BOD_5 and suspended solids discharges will lower energy consumption and sludge generation in mill wastewater treatment systems and POTWs receiving mill wastewater, as discussed below.

11.3.1 Effluent Flows

The total effluent flow from an integrated bleached papergrade kraft and soda mill is normally between about 50 and 150 m^3/kkg pulp produced, although a few mills discharge significantly lower or higher flows (4). The average US bleached kraft and soda mill discharges approximately 95 m^3/kkg (5), which corroborates Mannisto` s graphs (4). For a 1,000 kkg/day mill, the average effluent flow is similar to that from a city of 250,000 people.

EPA found that bleach plant flows differ by furnish. The average flow for a hardwood line, not employing extended delignification, was 25 m^3/kkg pulp. The flow for a comparable softwood line was 37 m^3/kkg pulp. Bleach plant flows differ because the quantity of organic material removed from the pulp in bleaching hardwoods is approximately 50 percent less than that removed from bleaching softwoods. Thus, hardwood bleaching lines often use a smaller number of stages than softwood lines use and generate less wastewater.

11.3.1.1 Flow Reduction Resulting from Screen System Closure

The BAT element that has the largest affect on effluent flows is closure of the brown stock screening systems ("closure" eliminates all planned effluent discharges from the screen room). EPA` s records show that approximately half the bleached kraft mills still operated open screen rooms in 1995 (EPA BAT Baseline Database) (6). EPA does not have data tabulating the effluent discharges from these screen rooms. Therefore, EPA estimated flow from open screen rooms using a mass balance assuming normal pulp consistencies. Results show that

an open screening system could contribute up to 70 m^3/kkg pulp, if all dilution is by fresh water. EPA ultimately rejected this mass balance analysis, however, because it concluded that screening systems were unlikely to operate with such high discharges today.

Springer (1986) states that a poorly designed and operated open screen room could require up to 150 m^3/kkg fresh water, thus causing a similar amount of effluent to be discharged (7). He also states that an older open screen room can be operated with 20 to 25 m^3/kkg discharge. In the TDD, EPA showed that the average effluent flow from the pulping area of a group of mills that included both mills with open screening and mills with closed screening systems was 16.4 m^3/kkg pulp. This amount includes the unbleached white water from the screen room, digester condensates, and miscellaneous flows. Based on these data, EPA concluded that discharges typical for open screen rooms could range from 10 to 25 m^3/kkg pulp. Thus, the conversion of a screen room from open to closed will typically reduce mill effluent flow by 10 to 25 m^3/kkg pulp, or approximately 10 to 20 percent from the average mill flow (95 m^3/kkg).

11.3.1.2 Flow Reduction Resulting from BMPs

BMP implementation will reduce effluent flow in three ways:

`   The recovered black liquor will likely be reused instead of discharged to the mill effluent treatment system. The objective of BMPs is to reduce discharge of organic substances by improving the degree of process closure of the mill. Although up to 34 kg black liquor solids per ton pulp may be recovered as a result of BMPs, the effects on flow are modest. The quantities have been estimated for each mill and are generally in the order of 1 m^3/kkg pulp.

`   The attention paid to miscellaneous discharges and the efforts that will be made to avoid clean water discharges diluting the recovered spills will result in a further reduction, as estimated by EPA, in effluent discharges of 1 to 2 m^3/kkg in most mills.

`   Since mills are expected to segregate clean cooling water to avoid dilution of spilled black liquor, it will be possible to either discharge these clean waters separately from contaminated wastewater, or to reuse the clean water. Reuse of clean water could result in about 2 percent reduction in effluent flow from mills that choose to make use of this potential benefit of BMPs.

11.3.1.3 General Effects of BAT on Effluent Flows

Other than closing screen rooms and BMPs described above, no elements of the two BAT options will reduce effluent flows directly. However, the application of current

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engineering practices to the design of new systems and equipment will result in conservation of water. The greatest improvements are likely to be seen in mills currently using relatively high quantities of water.

Retrofitting an oxygen delignification system (which would be a practical necessity for compliance with Option B) has no direct effect on effluent flows by itself. Some mills have reported reductions in effluent flow in oxygen delignification projects because it is normal practice to close the screen room process by recycling the screen decker filtrate to brown stock washing when oxygen delignification is installed. In some cases, as noted in the TDD, when the unbleached pulp kappa number into bleaching is reduced, one or two complete bleaching stages can be retired (e.g., convert a CD Eo DED bleach plant to an O D EopD). Such action could reduce effluent flows by about 15 m^3/kkg pulp. In rare cases, oxygen delignification will result in some water conservation if lower unbleached pulp kappa number into bleaching allows the use of reduced wash water flow in the first bleaching stage.

Mills reduce the kappa number of unbleached pulp entering the bleach plant by two types of extended delignification: extended cooking and oxygen delignification. EPA`s data, presented in Table 11-2, show lower bleach plant effluent flows in mills with extended cooking or oxygen delignification.

When upgrading the first chlorine/chlorine dioxide stage to high or 100 percent chlorine dioxide substitution for chlorine, low consistency operations are usually converted to medium consistency, or increase the use of recycled bleach filtrates for pulp dilution to raise the temperature without incurring the cost of direct steam heating. These changes can lead to a reduction in bleach plant effluent flows of about 12 m^3/kkg pulp in softwood mills and 5 m^3/kkg in hardwood mills. Such improvements are most likely to be made in mills which have high effluent flows.

During mill renovation, new equipment is not installed in isolation. Instead, it is common practice to modernize the mill area involved, at least to some extent. Modern equipment is generally designed to conserve water more effectively than older designs. Many details can be involved, such as the replacement of packing on shafts with modern mechanical seals that use little or no water, or reduction in cooling water requirements by more efficient design. These modifications will generally reduce effluent discharges modestly, but it is difficult to provide realistic numeric estimates.

11.3.2   Solid Wastes

EPA estimates that implementation of Option A and Option B would result in a reduction in the generation of sludge in the effluent treatment systems. The reduction in generation of wastewater treatment sludge results from the decrease in organic load discharged to the effluent treatment system.

Commenters have expressed concerns that modifying mills to approach closure of the water cycle would result in large increases in solid waste requiring disposal. This issue always requires careful consideration, since improving effluent discharges by simply transferring wastes to another medium is clearly undesirable. The only available study supported by detailed engineering analysis and mill experience which considers the technologies involved in the present discussion shows that the rate of solid waste generation for a closed cycle mill would be lower than the current industry average by a factor of about three (8).

EPA has not found any detailed analysis in the literature which would suggest that solid waste generation would increase as a result of partial mill closure. The process changes that are elements of Options A and B are not expected to cause the generation of additional quantities of solid waste. None of the "very low effluent" mills discussed in the Technical Support Document for the Voluntary Advanced Technology Incentives Program generates large quantities of solid waste (1). Review of the pollution prevention technologies being developed for flow reduction for the pulp and paper industry suggests that increased solid waste generation can be readily avoided.

Because of impacts on energy use, implementation of BAT would cause some small change in solid waste generation at utility power stations burning coal. Option A would increase generation of solid waste, while Option B would cause a reduction. EPA has considered these changes to be negligible and has not attempted to estimate quantities of this material.

11.3.2.1   Current Sludge Disposal

An analysis of sludge disposal practices in the late 1980s showed that mills bleaching chemical pulp were disposing of 2.5 million dry kkg/year (9). Since the bleached papergrade kraft subcategory makes up about 90 percent of the bleached chemical pulp production, for this analysis, EPA assumed that this subcategory also contributes approximately 90 percent of the sludge. The sludge generation rate is equivalent to approximately 80 kg/kkg pulp produced.

As reported in 1991, approximately 52 percent of the sludge was being landfilled, 20 percent stored in surface impoundments, 9 percent incinerated, and 7 percent applied (presumably beneficially) to land. The rest was disposed of by various means including ocean outfall, selling, and mixtures of two or more of the above.

11.3.2.2   Primary Sludge

The overall tightening of mill systems due to closing screen rooms, BMPs, and the improvement of washing systems will reduce fiber losses. The reduction in fiber discharges will vary, and will be the greatest in mills presently discharging relatively large amounts of fiber. As discussed in Section 11.2.1, fiber losses of 0.1 to 0.3 percent would be eliminated. Assuming, on average, that 0.2 percent fiber is eliminated, approximately 140,000 kkg/yr fiber would be recovered if all screen rooms previously open were closed. This figure includes the general

tightening up that would be associated with implementation of BAT, PSES, and BMPs due to reductions of spills and also reductions in flows of the weak white water and filtrates that typically contain 20 to 100 mg/L fiber.

NCASI estimated that the average bleached kraft mill generated 57 kg of sludge per ton product in 1989, on the basis of an industry survey (10). Consideration of mill practices suggest that this quantity has been reduced somewhat since 1989, but EPA has no definitive data. The average reduction of 0.2 percent (2 kg/kkg) derived from above sources would represent a reduction in primary sludge discharges of 4 percent from the 1989 discharges. Because closed screen rooms, BMPs, and effective brown stock washing are common to both Option A and Option B (and because the extended delignification process unique to Option B does not affect fiber losses), EPA estimates no difference of primary sludge between the options.

11.3.2.3   Secondary Sludge and BAT

All but one of the bleached papergrade kraft mills in the US employ secondary wastewater treatment either on site or through a POTW. (The mill without secondary treatment discharges to the ocean.) Mills either have activated sludge treatment systems (AST), aerated stabilization basins (ASB), or some combination of these types. In order to consider the effects of Options A and B on secondary sludge, EPA considered not only secondary wastewater treatment systems at direct-discharging mills with ASTs, but also POTWs with ASTs receiving predominantly bleached papergrade kraft and soda effluent. All secondary treatment systems create sludge by converting dissolved organic material (BOD_5) into biomass. However, much more sludge is generated by AST than by ASB. In addition, sludge is routinely wasted from AST while it is typically left to degrade biologically in an ASB. Therefore, the estimate of the reduction in solid waste generation resulting from BAT focused on mills employing AST.

The quantity of solid waste produced by activated sludge or similar wastewater treatment processes is proportional to the BOD_5 load on the treatment system. Secondary wastewater treatment sludge can be the major source of solid waste in a mill. Four of the nine POTWs that process wastewater from indirect-discharging bleached kraft mills use aerated stabilization basins, and, therefore, generate little sludge for disposal. The other five POTWs use AST (11). Totaling direct and indirect dischargers that use AST, about 30 percent of the bleached papergrade kraft mills use AST and produce secondary wastewater treatment sludge.

Black liquor solids have a BOD_5 of approximately 0.3 kg BOD_5/kg BLS. Approximately 0.6 kg of biological (secondary) sludge is generated in an activated sludge system for each kg BOD_5 applied (12). This relationship was used along with an estimate of the reduction in BLS that would result from implementation of Option A and Option B and 1995 baseline sludge generation estimates to calculate the associated changes in sludge generation (13). Additional BLS combusted and decreases in BOD_5 and sludge generation are shown in Table 11-3.

In 1991, EPA determined that the 104 bleached chemical pulp mills discharged approximately 2.5 million dry tons per year of sludge from wastewater treatment plants (14). No reason exists to suppose that a large change has taken place since that time. The bleached papergrade kraft subcategory produces approximately 90 percent of the pulp produced by bleached chemical pulp mills, and consideration of the processes generally used indicates that the quantity of sludge discharged will be approximately in proportion to production.

The foregoing quantities of solid waste include only the dry material. If the sludge is landfilled, it will probably be about 40 percent dry concentration, so the total weight basis requiring disposal will be about 2.5 times the dry quantity.

11.3.2.4 Dioxin and Furan in Sludge

Sludge generated at bleached papergrade kraft and soda mills may contain dioxin and furan if these pollutants are found in wastewater treated at these mills. At proposal, the Agency estimated that the mills in these two subcategories generated 177 g/yr toxic equivalent (TEQ) dioxin in their wastewater treatment sludge. Since the proposal, industry has significantly reduced the level of dioxin and furan in its wastewater. The Agency estimates that the dioxin and furan content of the sludge has decreased similarly, to approximately 50 g/yr TEQ.

The control technologies that form the basis of the BAT limitations and PSES promulgated today limit the concentration of dioxin and furan allowed to be discharged. As a result, the Agency estimates that when fully implemented, the combined application of BAT limitations and PSES will reduce the present sludge loading of dioxin TEQ by 43 g/yr, approximately an 85 percent reduction from current levels.

11.3.2.5 Aerated Stabilization Basins

Approximately 70 percent of mills in the bleached papergrade kraft subcategory use ASBs, some in combination with activated sludge treatment (6). Though ASBs generate much less sludge than activated sludge treatment, they often become partially filled with sludge after a number of years of operation, and require dredging. Lightly loaded ASBs have the ability to mineralize organic sludge, and operate for many years without cleanout. As discussed above, the BAT options will reduce the discharge of BOD_5 and suspended solids to treatment and thus reduce ASB dredging frequencies.

11.3.2.6 Potassium and Chloride Purges

In a conventional, relatively "open" kraft mill, non-process elements such as potassium and chloride are eliminated from the system by discharge in the mill`s wastewater. Many authors, including Tran (1990) (15), have shown that as mills approach process closure, the concentrations of chloride and potassium throughout the liquor system rise, and can cause plugging on the surfaces of the chemical recovery boilers exposed to the products of combustion (i.e., fireside).

Potassium and chloride concentrate in the dust caught in the electrostatic precipitator of the kraft mill recovery boiler. To control the concentrations of potassium and chloride in the mill`s cooking cycle, some mills with excellent BMPs and operating practices which minimize losses from the green/white/black liquor cycle have to remove and discharge a portion of the precipitator dust, which is a mixture of inorganic salts of sodium and potassium. The total quantities of these substances discharged with the precipitator dust is identical to the quantity previously discharged with the pulp mill and bleach plant effluents. The point of discharge from the cycle has simply moved.

The precipitator dust discharge, which may be up to 20 kg/kkg pulp, has been described as a solid waste discharge in some documents. However, in many mills, the dust never exists in dry form except between the plates of the precipitator, and is normally discharged as a solution in the effluent[2]. Today, mills commonly discharge this material with the effluent.

Most of the potassium in a mill system enters with the wood and purchased chemicals (15). The potassium entering with the wood will be discharged by any mill, whether operating like a pre-1970 mill, or in accordance with the most advanced BAT criteria. The quantity of potassium entering with the chemicals, and hence discharged, will be less in the more advanced mills, since the quantity of chemicals purchased will drop due to recycle. The mill operator is also likely to avoid purchasing contaminated chemicals to minimize the problems caused by potassium in the mill.

11.4   Energy Impacts

11.4.1   Overview of Energy Impacts

Sections 304(b) and 306 of the Clean Water Act specifically direct EPA to consider the energy requirements of effluent limitations guidelines and standards it establishes. EPA estimated the impacts of BAT, PSES, and BMPs on the energy use of the 86 mills with production in the bleached papergrade kraft and soda subcategory. For Option A and Option B, combined with BMPs, EPA analyzed the following changes in energy use:

`   On-site electrical demand within the mill;

`   Electrical demand for wastewater treatment;

`   Pulp mill and bleach plant process steam demand; and

`   Off-site electrical demand resulting from manufacture of bleaching chemicals (primarily raw materials for on-site ClO_2 generation).

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[2]Quantities are small. The BFR process at Canton, NC, which is the largest chloride removal system operating in the US, discharges approximately 30 m^3/day, or 0.03% of total mill discharge flow.

Table 11-4 presents EPA's estimate of the effect of Option A and Option B on energy consumption relative to consumption in 1995. The estimated energy impacts were converted to an "oil equivalent," to conveniently present the combined changes in thermal energy and electric power. As depicted in Figure 11-1, EPA estimated that Option A would result in an increase in oil consumption of 840,700 bbl/year while Option B would result in a decrease in oil consumption of approximately 1,535,000 bbl/year. The energy savings demonstrated by Option B is primarily due to replacement of a portion of chlorine dioxide bleaching chemicals by oxygen (in oxygen delignification). Manufacture of oxygen requires substantially less electrical energy that the manufacture of chlorine dioxide of equivalent bleaching power.

11.4.2   Estimation of Energy Impacts

Estimates of the energy impacts of implementing the technology required to meet Option A and Option B are discussed in this section.

11.4.2.1   Calculation Methodology of Energy Impacts for Option A and Option B Process Changes and BMPs

EPA evaluated the effect of each process change element of Option A and Option B in each mill on demand for steam and electrical energy. The process changes which have a significant effect are listed in Table 11-5. Items described as "insignificant" or "minor" were excluded from calculations of changes in energy consumption because they have no discernible impact within the accuracy of the estimate. In addition to the explicit process changes, the consequential effects of reducing effluent flow and BOD load have an effect on energy consumption in the mills` wastewater treatment plants.

EPA estimated, on a mill-specific basis, the process changes that each BPK mill would need to make in order to implement Option A and, separately, Option B. Based on these estimates, EPA calculated the mill-specific electricity involved. Details of the assumptions and associated equations are defined in the BAT Cost Model Support Document (16). The cost model equations used for the calculations in the report reflect comments received by EPA from the pulp and paper industry and the public on the 1993 and 1996 versions of the cost model. The calculations included changes in power demand for both the mill site and for the manufacture of the principal bleaching chemicals used for each process variation.

The manufacture of sodium chlorate for mill-site chlorine dioxide generation is a major factor in off-site electrical energy demand. Production of chlorine dioxide requires approximately 11 kWh/kg, whereas the equivalent quantity of chlorine requires only about 5 kWh/kg, and the equivalent quantity of oxygen about 1 kWh/kg. All of the potential bleach plant modifications will reduce the demand for electrolytically produced caustic, thus reducing demand for off-site electrical energy. The difference in power required for the various alternative bleaching processes are calculated in the cost model, and are included in the data presented in Figure 11-1 and Table 11-4.

For both Option A and Option B, the need to generate steam by burning fossil fuel at the mill site will be reduced by the heat generated from burning black liquor recovered by improved washing, closing the screen rooms, and BMP. For Option B, a small additional increase in recovery of heat energy will occur due to the incorporation of oxygen delignification, which recovers organic material otherwise discharged to the effluent treatment system in mills that do not use oxygen delignification. EPA estimated that the recovered heat would be approximately one percent of the base case heating value of the black liquor burned at the mill. Heat energy is also consumed in evaporating the recovered black liquor and providing heat to oxygen delignification systems. The net effect was calculated for each mill, and the industry-wide total is shown in Figure 11-1 and Table 11-4.

11.4.2.2   Calculation of Energy Impacts from Effluent Treatment System Operation

Wastewater from all but one US bleached kraft mill is treated in a biological wastewater treatment system prior to discharge to the environment. These treatment systems are equipped with aerators to facilitate biochemical oxidation of the wastewater BOD_5 load. As described in Section 11.3.2.3, implementation of BAT or further pollution prevention technology will reduce the BOD_5 load requiring treatment.

Biodegradation of BOD_5 requires approximately 1.25 kWh per kg BOD_5 to adequately aerate the wastewater (derived from Kocurek, 1992; also a widely accepted value) (12). As described in Section 11.3.2.3, the effects of Option A and Option B on BOD_5 loads to the effluent treatment systems were calculated mill by mill on the basis of the quantity of recovered organic material (black liquor solids). EPA assumed that each kg of black liquor solids would exert 0.3 kg BOD_5 and the reduction in BOD_5 load was calculated for each mill. Where the BOD_5 load is reduced, mills can generally reduce the electrical energy used for aeration of the biological treatment systems. This reduction in energy consumption in effluent treatment is included in the total energy impacts for Option A and Option B shown in Figure 11-1 and Table 11-4.

Where a substantial reduction in effluent flow is realized by the pollution prevention measures in the mill, minor modifications to the effluent treatment systems may be required so that the mill could take advantage of the energy savings mentioned above. These modifications might involve baffles to direct flow of effluent in an ASB, or bypassing part of parallel sets of equipment. See Section 10 for further discussion.

11.4.2.3   Equivalence of Various Forms of Energy

EPA calculated an "oil equivalent" to conveniently present the combined effects of the changes in thermal energy and electric power. The oil equivalent is based on the assumption that all nuclear, hydro-electric, waste fuel, natural gas, coal, co-generation, and wind power systems across the country are operated at their maximum capacity, and that any increase or decrease in fuel electric power demand caused by the effluent guidelines regulations is supplied by conventional condensing-type oil fired power stations. (If EPA assumed that

additional electrical demand would be supplied by coal or natural gas burning facilities, then the predicted effect on fossil fuel consumption would be quite similar. It is expressed in terms of oil equivalents here for convenience of the reader. Coal equivalents could also reasonably be used.)

For example, a mill burning all its black liquor and hog fuel would normally also burn some purchased fossil fuel (oil, coal, or natural gas) to generate additional steam not produced by the recovery boiler and power boiler. All the black liquor must be burned, but the mill cannot normally increase the quantity of black liquor generated, since it is directly related to the pulp production rate. The hog fuel is relatively inexpensive, so all available material will be burned at all times, subject to any limitations in wood burning equipment. Any change in the requirement for process steam will be supplied by changing the quantity of fossil fuel purchased and burned.

Many mills also generate some or all of the electric power they require by passing steam through turbines prior to its use as process heat. This power (known as co-generated power) is relatively inexpensive, so mills normally operate their co-generation equipment to its maximum potential. Some generate more power than is required on site, and sell the surplus to the local utility or other customer. Whether the mill is a net buyer or seller of power, any change in on-site power demand will be passed on to the national electrical power grid, reflecting ultimately in the load on utility stations.

The overall efficiency of conversion of thermal energy in fossil fuels to electricity delivered to consumers is approximately 25 percent, because thermal power stations ultimately reject approximately two-thirds of the thermal energy derived from combusted fuel due to the thermodynamic properties of steam. Energy losses to the stack gas and mechanical and electrical losses occur in the turbines, generators, and distribution system. In addition, a small fraction of the power generated is used in the utility plant itself for motors, electrostatic precipitators, and other necessary auxiliary equipment.

To convert the steam demand calculated as tons per day to equivalent barrels of oil, EPA made the following assumptions. EPA assumed a steam plant operating efficiency of 75 percent, a useful enthalpy of one ton of process steam at a typical mill as 2.7 GJ, and a heat content of 1 barrel of oil equal to 6 GJ. The exact values vary up to several percent from those values assumed from mill to mill, but such variations are minor since the actual change in energy consumption which would result from implementation of the effluent guidelines is only a few percent total, as shown in Table 11-4.

11.4.2.4 Changes in Energy Consumption Relative to Industry Total

In order to determine whether the estimated energy requirements of Option A and Option B pose unacceptable impacts, EPA compared them to the total energy consumption of the bleached papergrade kraft and soda subcategory. EPA estimated the total oil equivalent by adding the purchased electricity and fossil fuels reported in AF&PA's 1995 annual report (17) with EPA` s estimate of off-site power consumption for chemical manufacturing (DCN 14510).

For the bleached papergrade kraft and soda subcategory, EPA estimated the total oil equivalent energy consumption to be 117 million bbl/year. The fractional change in this total energy consumption for Options A and B are shown in Table 11-4. Option A represents a 1 percent increase, while Option B would result in a 1 percent reduction in subcategory energy consumption.

11.5   Atmospheric Emissions

Sections 304(b) and 306 of the Clean Water Act specifically direct EPA to consider the air pollution impacts of effluent limitations guidelines and standards it establishes. EPA estimated the impacts of BAT, PSES, and BMPs on the generation and emission of air pollutants by the 86 mills with production in the bleached papergrade kraft and soda subcategory. As detailed in this section, EPA analyzed the air emissions impacts of Option A and Option B. These options will affect atmospheric emissions in a number of ways, as follows:

`   Control technologies that form the basis of Option A and Option B involve changes in processes used to produce bleached pulp. As discussed in Section 11.5.1, air emissions decrease for some air pollutants and remain unchanged for others.

`   Mills will be burning material in the recovery boiler that was previously discharged with the effluent because of the substantial improvements in overall mill closure discussed in Section 11.3. This practice will tend to marginally increase emissions of many substances to the atmosphere by up to one to two percent, as discussed in detail in Section 11.5.2.

`   The location of points of emissions of carbon dioxide from mill sites will change, as discussed below, but the total emission will not.

`   The changes in overall energy consumption discussed in Section 11.4 will change atmospheric emissions from on-site and off-site energy production facilities (increase for Option A and decrease for Option B).

`   A localized increase in emissions of carbon monoxide will occur due to increased chlorine dioxide substitution.

11.5.1   Emissions Due to Mill Process Changes

The control technologies that form the basis of the effluent limitations guidelines and standards involve changes in the processes used to produce bleached kraft pulp. These changes affect the rate at which air pollutants, including HAPs, are emitted from pulping and bleaching processes. As shown in Table 11-6, the process changes at bleached papergrade kraft facilities subject to BAT, PSES, and BMPs decrease the emissions of some HAPs but have little impact on others. For example, the elimination of chlorine and hypochlorite from bleaching

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processes as part of the basis for BAT and PSES will reduce the emission of chloroform in the bleached papergrade kraft subcategory by 64 percent but will have little impact on the emission of methanol. The application of BAT, PSES, and BMPs for the bleached papergrade kraft and soda subcategory will reduce the emission of total HAPs from 149,000 Mg/year to 139,000 Mg/year (7 percent reduction). The application of BAT, PSES, and BMPs plus MACT I, II, and III for the bleached papergrade kraft and soda subcategory will reduce total HAP emissions from 149,000 Mg/year to 59,200 Mg/year (60 percent reduction).

11.5.2   Emissions Due to Burning Increased Quantities of Black Liquor

Option A or Option B, combined with BMPs, will result in recovery and burning of increased quantities of black liquor, as discussed in Section 11.3.2.2. EPA calculated the changes in quantities of black liquor generated for each mill for Options A and B (16). EPA estimated the change in atmospheric emissions by applying emission factors (18,19,20,21) developed in support of EPA`s MACT II NESHAP to these changes in black liquor firing rates. These estimates, before and after MACT II is applied, are presented in Tables 11-7 and 11-8. Emissions after MACT II controls are implemented are only presented in Table 11-8.

The underlying assumption for calculation of the marginal air emission increases presented in Table 11-7 and Table 11-8 is that the emissions from a recovery boiler are proportional to the quantity of fuel fired. EPA believes that this assumption will generally lead to an overestimate of the actual emissions for the reasons discussed below.

Depending on the current status of a mill, three alternative scenarios[3] exist:

`   **Recovery Boiler Operating Below Capacity**

If the recovery boiler is operating below its maximum capacity, then the introduction of additional black liquor will raise the bed temperature, and the associated increase in feed of combustion air will increase turbulence. As discussed by many authors, increasing boiler load will normally reduce emissions of organic pollutants, provided the proper combustion conditions are maintained.

Particulate emissions would perhaps increase due to the increased gas flow through the precipitator, but increasing the bed temperature in a recovery boiler improves retention of sodium in the bed, thus reducing particulate formation. SO_2 emissions would drop because raising the bed temperature reduces sulfur emission. One characteristic of recovery boiler combustion conditions is that when SO_2 emissions drop, HCl emissions also drop. Many investigations have shown that SO_2 and HCl emissions drop to

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[3]Discussed in detail in the Analysis of Impacts of BAT Options on the Kraft Recovery Cycle (1997) (2) and the BAT Cost Model Support Document (1996) (16).

essentially zero in boilers with hot smelt beds and adequate combustion conditions. While the increased liquor firing rates that result from implementation of Option A and Option B with BMPs, will not necessarily cause sufficient rise in bed temperature to eliminate the SO_2 and HCl emissions, increased rates will present mills with the opportunity to modify recovery boiler operation to reduce emissions. Thus, a simple assumption that emissions are proportional to firing rate results in an apparent overestimate of emissions from boilers currently operating below capacity.

`   **Boiler Operating at Full Capacity: Mill Chooses to Upgrade the Boiler to Accommodate the Additional Black Liquor**

Recovery boilers are typically upgraded by air system modifications and firing higher concentration liquor. Both result in raising the furnace temperature while upgraded air systems also improve turbulence. The results are the same likely reductions in air emissions discussed above (22).

`   **Boiler Operating at Full Capacity: Mill Chooses to Oxidize the Black Liquor to Reduce Its Heating Value**

In this case, the solids feed to the boiler will rise, but the heat input will not since the heating value of the liquor is reduced by oxygen black liquor oxidation. The demand for combustion air will drop (due to less organic feed and since the products of oxidation introduce oxygen to the stream), so the stack gas flow will drop. Because gas flow through the boiler is the key to emissions of several pollutants, emissions will not likely rise in proportion to the fuel feed. Black liquor oxidation can accommodate a thermal load increase of up to 5 percent. Therefore, if a mill`s thermal load increases by less than 5 percent, black liquor oxidation can reduce total thermal load below the mill`s baseline thermal load.

In all cases, TRS emissions are likely to be reduced by the above-mentioned increases in temperature and upgrades to the boiler. In addition, sulfur dioxide emission increase estimates are likely overstated because they do not account for the fact that some mills in sensitive areas for sulfur dioxides already have sulfur dioxide controls in place or may choose alternative controls available in the final MACT rule that mitigate these increases.

The discharge of carbon dioxide from the recovery boiler stack will increase in all three scenarios, but will be balanced by a corresponding reduction in emissions from the effluent treatment system and receiving water, as discussed in Section 11.5.3.

The increases in discharges of particulate HAPs due to changes in black liquor firing are overshadowed by the effects of changes in quantities of oil fired in power boilers, as shown in Table 11-9.

11.5.3 Emissions Due to Changes in Energy Consumption

As discussed in Section 11.4 and summarized in Table 11-4, Option A and Option B will have an effect on total energy consumption. For the analysis presented here, EPA estimated changes in on-site steam demand, on-site electric power consumption, and off-site electric power consumption for each mill individually. On-site steam demand is met by power boilers that burn black liquor, wood, coal, or oil and by recovery boilers burning black liquor. Electrical demand is typically met by off-site electric power generating stations that burn coal, oil, natural gas, or use nuclear or hydro energy. For the purpose of this analysis, EPA calculated an oil equivalent to combine the effects of all energy changes.

As discussed in Section 11.4 and summarized in Table 11-4, both Option A and Option B, in combination with BMPs, result in a net increase in combustion of black liquor solids and a corresponding fuel benefit. The decrease in steam demand from the fossil fuel fired boilers will result in less combustion in on-site power boilers and lower emissions from those sources that offset the increased emissions from the recovery boilers discussed in Section 11.5.2. Option A results in a net increase in off-site electric power consumption and a net decrease in on-site power consumption. The on-site electrical savings is further decreased by the decrease in steam demand so that, as shown in Table 11-4, the mill realizes a net energy savings. However, the energy demand associated with Option A results in a net global increase.

Combustion of oil causes emissions of SO_2, carbon dioxide, and trace quantities of various metals (particulate HAPs). Particulate HAPs are also associated with combustion of black liquor, as discussed in Section 11.5.2. The changes in air emissions due to estimated changes in energy consumption are shown in Table 11-9. Table 11-9 also presents total emissions for SO_2 and particulate HAPs resulting from BLS combustion (shown in Table 11-7) plus oil combustion. Changes in carbon dioxide emissions are discussed in Section 11.5.4.

11.5.4 Greenhouse Gases

The earth radiates long-wavelength radiation that is absorbed by water vapor and carbon dioxide (CO_2) in the atmosphere near the earth`s surface. Because both water vapor and $CO_2$ are transparent to the incoming, warming, solar radiation but absorb the long-wave radiation from the earth`s surface, the net effect of increases in atmospheric CO_2 and water vapor is a warming of the earth`s atmosphere. This effect has been termed the "greenhouse effect" and CO_2 and water vapor have been termed "greenhouse gasses." Anthropogenic generation of water vapor is minuscule relative to atmospheric recycling and is normally ignored in greenhouse gas analysis. Therefore, water vapor is ignored here.

CO_2 is an ultimate product of all combustion processes, including the combustion of fossil fuels to generate electricity and the combustion of wood and black liquor at a pulp mill. CO_2 is also the ultimate product of the biodegradation of water-borne organic wastes generated by a pulp mill. This biodegradation occurs in the biological wastewater treatment system, with the ultimate disposal of sludge, and in the receiving stream.

The generation of CO_2 attributable to the production of bleached pulp equals the carbon taken into the mill with the wood and other raw materials, less the carbon that leaves the mill as product plus the CO_2 generated during the production of energy needed to produce the product. Thus, to minimize the generation of greenhouse gasses, yield of product from the wood must be maximized and energy use minimized. As discussed in Section 11.4, production of bleached pulp consumes energy not just at the pulp mill, but also during the production of bleaching chemicals, with chlorine dioxide requiring the most energy.

EPA examined the effect of Options A and B combined with BMPs on the generation of CO_2 by considering the overall mill carbon balance and the energy balance. As discussed below, EPA concluded that neither option would have an impact on the total emission of greenhouse gasses from mills due to pulp processing. However, the changes in energy consumption will have the effect of increasing CO_2 emissions for Option A while they will be reduced for Option B. EPA concludes that the increased CO_2 emissions attributable to Option A pose no unacceptable non-water quality environmental impact.

11.5.4.1   Mill Carbon Balance

In this context, the mill carbon balance includes all pulping, bleaching, recovery cycle, effluent treatment, and residual effects on the final receiving water. The effects of fuel burned for energy production are discussed separately below.

All carbon that enters the mill as a component of raw material, wood, or purchased chemicals leaves by one of the following paths:

As part of the product	Will not be affected by either option.
As CO_2 from combustion of black liquor or recalcination of lime in the recovery cycle	Will be slightly increased by both options but offset by reduction in organic load in mill effluents and in energy demand on power boilers.
As organic material in mill effluents	Oxidized to CO_2 in biological treatment systems and by subsequent biological action in the receiving waters. Some of the material may be recovered as sludge from waste treatment plants, and ultimately converted to CO_2 by incineration or degradation in landfills.
As organic gases from digester	Will be in the order of 1 kg/kkg pulp. MACT I combustion control devices will reduce these emissions by approximately 98 percent. The rest will oxidize to CO_2 in time in the atmosphere.

Thus, nearly all the carbon entering the mill eventually reaches the atmosphere as carbon dioxide, except for the carbon component of the product.

The quantity of carbon entering the mill will not be modified significantly by implementation of BMPs and Option A or Option B, because pulp yield is not affected by these technologies (see Section 11.2.2). However, as discussed in Section 11.2, mills may experience decreased wood consumption up to 0.3 percent for both options. Minor changes in carbon entering the mill will include increased use of methanol as a reductant for manufacture of chlorine dioxide. The recausticizing cycle will have to process additional quantities of lime mud (calcium carbonate) because more black liquor will have to be processed as a result of the implementation of BAT. The additional carbon dioxide released in the calcination reaction in the lime kiln has its origin in the wood used in the digester, and is balanced by a reduction in carbon dioxide released by biological oxidation of the mill`s waste waters.

To put these assumptions in perspective, the quantity of carbon entering the mill with the wood should be compared with the above-mentioned minor sources.

The worst case for increased carbon input with methanol would be conversion of a softwood mill using no chlorine dioxide in the first bleaching stage to 100 percent substitution, and installing one of the methanol reduction processes to produce chlorine dioxide. Total chlorine dioxide consumption would be approximately 40 kg ClO_2/kkg pulp which would require a feed of 150 kg methanol per ton ClO_2 (equivalent to 6 kg/kkg pulp). The methanol would be discharged to the effluent as an organic by-product of ClO_2 manufacture and would be oxidized

to carbon dioxide in the biological treatment system, producing approximately 8 kg carbon dioxide/kkg pulp. The end result would be under 0.3 percent of the total mill emission. The incremental emission of CO_2 would be less for mills that currently operate methanol reduction ClO_2 plants and for mills already using high ClO_2 substitution. If a mill uses extended cooking or oxygen delignification then the amount would be cut further because of reduced chlorine dioxide consumption.

11.5.4.2 Effect of Energy Production and Carbon Sequestration on Carbon Dioxide Emissions

Fossil Fuel Consumption - As discussed in Section 11.4 and summarized in Table 11-4, both Option A and Option B will have an effect on total energy consumption that can be represented as a quantity of oil burned for electric power generation. The carbon content of fuel oil is typically in the range of 83 percent to 88 percent. EPA assumed that the average carbon content of fuel oil burned is 85 percent, and calculated the effect of changes in energy consumption on carbon dioxide emissions. These changes, presented in Table 11-10, would occur primarily at electric utility stations remote from the pulp mills.

Assuming 85 percent carbon, and a typical heating value of 42 MJ/kg, fuel oil contains approximately 20 grams carbon per MJ. In the case of a boiler firing coal, the fuel would typically contain approximately 60 percent carbon, and have a heating value of approximately 28 MJ/kg. The carbon content of the coal is therefore approximately 21 g/MJ. Therefore, the carbon dioxide generation for production of a given amount of electricity varies little, regardless of the fuel used.

Carbon Sequestration - Mills may reduce wood consumption by up to 0.3 percent for both options, as discussed in Section 11.2. Approximately 2,500 kg wood is consumed to manufacture 1,000 kg of fully bleached kraft pulp (oven dry basis). Wood contains approximately 50 percent carbon, so that about 1,250 kg carbon are fed to a mill per ton product. Some of this carbon is incorporated into the product, while the remainder as carbon dioxide (approximately 760 kg carbon/kkg pulp (61 percent) or 2,800 kg ClO_2/kkg pulp) is emitted to the atmosphere by the pulping and bleaching process, including stack emissions (the majority) and biodegradation of effluents.

If a mill reduces wood consumption by 0.3 percent, carbon input to the mill is reduced by 3.75 kg carbon per ton product (13.75 kg CO_2 per ton product). With a yearly bleached papergrade kraft production of 29.2 million tons per year, 401,500 tons CO_2 per year is sequestered by decreased wood use. Sixty-one percent of the sequestered CO_2 would have been emitted to the atmosphere. Therefore, the net reduction in CO_2 emissions is 245,000 tons CO_2 per year.

Carbon sequestration lessens the impact of fossil fuel consumption on CO_2 emissions for Option A and further reduces CO_2 emissions for Option B. EPA concludes the increased CO_2 emissions pose no unacceptable environmental impacts.

11.5.5   Carbon Monoxide Emissions from Oxygen Delignification

Someshwar (1997) presented data on numerous tests of emissions from four full-scale oxygen delignification systems showing that they generated from 25 to 200 grams CO per ton pulp processed (23). The quantity of CO generated correlated loosely with the oxygen charge.

The proposed air emission control regulations under MACT I require that the vents from oxygen delignification system be incinerated, so that the rate of emission to the atmosphere will be substantially below the rate of generation of CO. Because such an incinerator would be burning various organic gases including methanol, the CO emission to the atmosphere will depend on the design and operation of the incinerator rather than the rate of formation of CO in the oxygen delignification system.

MACT I requirements will ensure efficient oxidation of CO from this source. Keeley (1997) suggests that at least 95 percent conversion of CO to carbon dioxide would be attained (24). Consequently, EPA does not consider that the exact rate of CO emission from the oxygen delignification reactors is important.

11.5.6   Carbon Monoxide from Chlorine Dioxide Bleaching

Downe (1996) expressed concerns that the increase in emissions of carbon monoxide (CO) associated with increases in use of chlorine dioxide (as would be encouraged by guidelines based on either option) would create difficulties for mills requesting permits under air emission control regulations (25).

11.5.6.1   Information Available Prior to 1996

Traditionally, carbon monoxide emissions from bleaching have not been considered significant relative to combustion sources in a pulp mill. However, Van der Merwe (1980) reported that bleaching with chlorine dioxide generated sufficient CO to kill a maintenance worker inside a bleaching vessel (26). Van der Merwe's supposition was subsequently discussed and confirmed by other authors in the context of being an occupational safety issue. As a common practice today, mills test vessels associated with chlorine dioxide bleaching for carbon monoxide prior to entry for maintenance and inspection.

Van der Merwe concluded:

` Chlorine bleaching of unbleached softwood did not generate CO;

` Sodium hypochlorite bleaching of softwood generated trace amounts of CO[4];

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[4]Elimination of hypochlorite bleaching is a process technology component of both Option A and Option B.

`   Chlorine dioxide delignification[5] of oxygen delignified hardwood and softwood pulp generated a concentration of CO of up to 3.2 percent in head space of a laboratory reactor; and

`   Chlorine dioxide delignification of softwood pulp that had not been previously delignified with oxygen generated much higher levels of CO than oxygen delignified pulp.

Van der Merwe also found that CO was generated when unbleached pulp (kappa 32) was bleached with hydrogen peroxide. However, unbleached pulp is never processed with hydrogen peroxide on an industrial scale unless the kappa number is first reduced to well below 20.

In independent work associated with investigations of bleach process yields, Kutney (1983) showed that CO is formed in bleaching, and that the formation is approximately proportional to the extent to which chlorine dioxide is substituted for chlorine (27). He confirmed the trends noted by Van der Merwe.

11.5.6.2   Recent NCASI Study of CO Emissions from Bleaching

Someshwar (1997) reviewed the literature on emissions for CO from chlorine dioxide bleaching (23). He also reported on measurements of CO emissions from six full-scale, operating bleach plants carried out by NCASI using Continuous Emission Monitoring (CEM) equipment and reported on various measurements for other operating mills by third parties.

The measurements reported by Someshwar include mass flows of CO per unit pulp production, whereas most other authors report only concentrations of CO generated.

Someshwar concluded:

`   The major contributors to CO emissions from the bleach plants were the chlorine dioxide bleach towers;

`   Emissions of CO from bleach plants were from 90 to 750 g/kkg pulp processed, with an overall average of 390 g/kkg;

`   Emissions of CO are roughly proportional to the ClO_2 charge applied to the entire bleach plant; and

`   Contributions to total CO emission from the bleach plant by hydrogen peroxide and extraction stages were small.

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[5]The term "chlorine dioxide delignification" is often used to refer to the first chlorine dioxide stage of a modern bleach plant.

The data reported by Someshwar are summarized in Table 11-11. EPA analyzed these data to determine which of the known variables in the bleaching process correlate best with the measured emissions of CO. Correlation with unbleached kappa number, wood type (softwood or hardwood), and level of chlorine dioxide substitution were examined. EPA attempted to discern a relationship between CO emissions and chlorine dioxide charge. The two sets of data which form a coordinated series of experiments (mill AA and mill SG) were examined separately and found to exhibit poor linear regression coefficients relative to equation (1). The best linear regression equation found for CO emission rate vs. total chlorine dioxide charge is:

$$\text{CO emission g/kkg pulp} = 7{,}780 \times \%ClO_2 + 220 \tag{1}$$

Equation (1) is shown in Figure 11-2. An alternative regression line which is forced to pass through the origin is also shown in Figure 11-2.

$$\text{CO emission g/kkg pulp} = 1{,}637 \times \%ClO_2 \tag{2}$$

The regression coefficient (0.146) is clearly poor. Although a definite trend toward increasing CO emissions with increasing use of chlorine dioxide exists, the relationship is loose, and not necessarily linear.

Increased use of chlorine dioxide results from mills electing to operate with high substitution rates (an element of both Option A and Option B) and by bleaching high kappa pulp. One could therefore expect mills using oxygen delignification to emit less CO than similar mills without oxygen delignification, as suggested by Van der Merwe (1980) (26). Someshwar does not indicate which mills in Table 11-11 use oxygen delignification (23). EPA assumed that mills showing unbleached kappa numbers which corresponded to the use of oxygen delignification or extended cooking are operating one (or both) of these processes.

EPA assumptions for individual data sets are shown in Table 11-11. On this basis, EPA calculated average carbon monoxide emissions for softwood mills with and without oxygen delignification as follows:

Mills with traditional cooking	439 g/kkg pulp
Mills with oxygen delignification or extended cooking	352 g/kkg pulp

The few data on hardwood bleaching showed no significant difference between mills with or without oxygen delignification.

11.5.6.3   Effect of BAT on Total Emission of CO

To assist in estimating the costs for Options A and B, EPA calculated the chlorine dioxide consumption for each mill. The total is shown in Table 11-12.

Based on the equations presented in Figure 11-2 and the 1995 bleached kraft subcategory production, the total estimated emissions of carbon monoxide from bleaching for 1995 baseline conditions, Option A, and Option B were calculated as shown in Table 11-12. The values shown in Table 11-12 for CO emissions per ton pulp differ from the values above because they refer to the total of hardwood and softwood pulp.

11.5.6.4   Carbon Monoxide Emissions from Bleach Plants vs. Total Mill Emissions

The total CO emissions from combustion of pulping liquors in bleached, unbleached, sulfite, and semi-chemical pulping mills is 274,000 tons of carbon monoxide per year. Approximately half the total production of chemical/semi-chemical pulp is bleached papergrade kraft.

Assuming that approximately half of the above-mentioned carbon monoxide emissions are from bleached papergrade kraft, the bleach plant emissions for Option A would represent approximately 9 percent of the total carbon monoxide emission from the liquor burning sources in the bleached papergrade kraft subcategory.

EPA concluded that implementation of Option A would increase emissions of CO from bleach plants by approximately 50 g/kkg pulp (about 30 kkg/yr for a typical mill), while Option B would cause an increase of approximately 7 g/kkg pulp. The emission increase due to Option A is approximately 10 percent of the average emission of CO from combustion sources in a mill. Emission control technology to reduce CO from boilers is well known and available. So, wherever "Prevention of Significant Deterioration" concerns exist, it would be feasible to reduce CO emissions from combustion sources to counter the increase in emissions from the bleach plant.

11.6   Impacts of New Source Performance Standards and Pretreatment Standards for New Sources (NSPS and PSNS) on the Bleached Papergrade Kraft and Soda Subcategory

EPA analyzed the projected non-water quality environmental impacts of Option A for the bleached papergrade kraft and soda subcategory for BAT, PSES, and BMPs based on complete substitution of chlorine dioxide for chlorine and other technology elements (see Section 8.2.1.1 for Option A technology description) in Sections 11.1 through 11.5 above. This section presents the non-water quality environmental impacts of a second technology configuration (NSPS and PSNS) which is equivalent to BAT, PSES, and BMPs with the addition of extended delignification (oxygen delignification or extended cooking) on a new 1000 kkg/d bleached papergrade kraft fiber line (See Section 8.2.1.2 for Option B technology description).

Table 11-13 presents the non-water quality environmental impacts of the selected technology basis for NSPS and PSNS, compared to conventional pulping and bleaching technology. These estimates are based on the same calculation methodology described under BAT and PSES, applied to a 1000 tpd model mill. Based on these estimates, EPA concludes that the process technologies that form the basis for NSPS and PSNS for the bleached papergrade kraft and soda subcategory pose no unacceptable non-water quality environmental impacts.

11.7 Impacts of Totally Chlorine Free (TCF) Technology on the Bleached Papergrade Kraft and Soda Subcategory

EPA analyzed the projected non-water quality environmental impacts of Option A for the bleached papergrade kraft and soda subcategory for BAT, PSES, and BMPs based on complete substitution of chlorine dioxide for chlorine and other technology elements (see Section 8.2.1.1 for Option A technology description) in Sections 11.1 through 11.5. This section presents the non-water quality environmental impacts of two TCF options, TCF-Peroxide and TCF-Ozone described in Section 8 of this document.

Table 11-14 presents the non-water quality environmental impacts of the two TCF options, compared to conventional pulping and ECF bleaching technology (Option A). These estimates are based on the same calculational methodology described under BAT. Based on these estimates, EPA concludes that TCF process technologies for the bleached papergrade kraft and soda subcategory pose no unacceptable non-water quality environmental impacts.

11.8 Impacts of BAT, PSES, and BMPs on the Papergrade Sulfite Subcategory

EPA analyzed the non-water quality impacts that result from implementing BAT, PSES, and BMPs at the 11 papergrade sulfite mills. Because the number of mills in this subcategory is significantly fewer and the size of these mills is generally smaller than the bleached papergrade kraft and soda subcategory, the non-water quality impacts are lesser in magnitude in the papergrade sulfite subcategory compared to the bleached papergrade kraft and soda subcategory.

11.8.1 Wood Consumption

EPA notes that the impacts of BAT, PSES, and BMPs results in up to 0.3 percent decrease in wood consumption for the bleach papergrade kraft and soda subcategory. Approximately two-thirds of this decreased demand, or 0.2 percent, can be attributed to reduced fiber loss due to the implementation of BMPs. The remaining 0.1 percent of decreased demand can be attributed to closed screening. EPA assumes that the demand for wood at papergrade sulfite mills will decrease up to 0.2 percent due to the implementation of BMPs. Closed screening is not a BAT, PSES, and BMPs technology element of papergrade sulfite subcategory and therefore will not result in decreased wood consumption.

11.8.2   Solid Waste and Effluents

The effects of this rulemaking on solid waste and effluents are discussed below.

11.8.2.1   BOD$_5$ and Sludge Generation

Implementation of BMPs will result in decreased solid waste generation from the recovery and rerouting of an incremental amount of red liquor to other processes that was once sent to wastewater treatment. Eight of the 11 mills can use a recovery furnace or incinerator to combust the recovered red liquor which was previously sent to wastewater treatment. The other three mills use other proprietary processes to recover chemicals and/or byproducts which are assumed to be able to accommodate the incremental red liquor that was previously sent to wastewater treatment. For estimation of solid waste impacts, EPA assumed that all 11 mills would be able to reduce the total organic load sent to wastewater treatment resulting from additional recovered red liquor by an amount equivalent to that achieved by mills employing a recovery furnace or incinerator. This assumption is reasonable because the three mills that do not use a recovery furnace or incinerator do employ various techniques to convert the organic load in the red liquor to a usable byproduct.

EPA estimates BOD$_5$ in untreated wastewater will decrease by 26,700 kg/d through the implementation of BMPs for the papergrade sulfite subcategory. EPA calculated an associated decrease in sludge generation of 2,470 kkg/yr for papergrade sulfite mills that use activated sludge treatment (several mills use aerated stabilization basins which do not produce sludge) based on the same calculation methodology described above for the bleached papergrade kraft and soda subcategory. EPA is projecting no change in BOD$_5$ and sludge generation as a result of implementation of BAT and PSES in the papergrade sulfite subcategory.

Since proposal, the dioxin and furan content of sludge at papergrade sulfite facilities has decreased significantly. As discussed in Section 11.3.2.4 for the bleached papergrade kraft and soda subcategory, the control technologies that form the basis of the BAT limitations and PSES promulgated today limit the concentration of dioxin and furan allowed to be discharged. As a result, these limitations will also reduce the sludge loading of dioxin at papergrade sulfite facilities by approximately 85 percent.

11.8.2.2   Effluent Flows

EPA assumed the reduction of effluent flow for papergrade sulfite mills will be comparable to the reductions achieved by bleached papergrade kraft and soda mills from the implementation of BMPs. EPA, therefore, estimates papergrade sulfite mills may achieve an effluent flow reduction of approximately 1 m^3/kkg pulp. EPA is projecting no additional change in effluent flows as a result of implementation of BAT and PSES in the papergrade sulfite subcategory.

11.8.3 Energy Impacts

As a result of implementation of BAT, PSES, and BMPs, EPA estimates off-site electrical energy consumption will decrease by 38,100 MMBTU/yr, primarily because of reduced bleaching chemical requirement. EPA estimates on-site electrical energy consumption will decrease by 1,050,000 MMBTU/yr, primarily because of decreased demand for operating wastewater treatment.

EPA estimates the change in on-site steam demand for the papergrade sulfite subcategory to be 10,300 MMBTU/yr. EPA calculated the change in steam demand by calculating the increase in steam demand required for the evaporation of the recovered red liquor at all 11 mills minus the additional steam that could be generated from the combustion of red liquor recovered at the seven mills that use recovery boilers. (Ingruber, Kocurek, and Wong (1985) report a range of red liquor heating values that average 14.9 MJ/kg. This value was used to estimate the amount of steam generated (28)).

The total impact of BAT, PSES, and BMPs for the papergrade sulfite subcategory decreases energy consumption by 1,080,000 MMBTU/yr.

11.8.4 Atmospheric Emissions

EPA estimates emissions of HAPs from papergrade sulfite mills will increase by 2.6 percent as a result of implementation of BAT, PSES, and BMPs. This increase in HAPs is projected to occur from implementation of BMPs that will capture of additional red liquor that was previously discharged, and burning of that red liquor in a chemical recovery boiler or incineration device at 8 of the 11 mills. The other three mills do not use a combustion-based process unit and therefore the capture of additional red liquor at these mills is assumed to not result in increased HAP emissions. The increased air emissions from the recovery of additional pulping liquor are based on the same calculation methodology described for the bleached papergrade kraft and soda subcategory with emission factors changed to reflect sulfite operation. The estimated emission does not represent a significant increase.

11.9 Impacts of New Source Performance Standards and Pretreatment Standards for New Sources (NSPS and PSNS) for the Papergrade Sulfite Subcategory

NSPS and PSNS that EPA is promulgating for the papergrade sulfite subcategory are equivalent to BAT and PSES, respectively. Therefore, EPA projects no non-water quality environmental difference between NSPS/PSNS technology and BAT technology.

11.10 References

A number of EPA documents involved in the development of the effluent guidelines are referred to herein. They are available in the public docket, except for portions

claimed as Confidential Business Information. This list includes documents prepared by the EPA and its contractors, as well as comments submitted to EPA concerning the rulemaking.

All other references listed below can be found in the open literature of the pulp and paper industry. Copies of the smaller documents are also in the public docket.

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Table 11-1

Summary of Impacts of Options A and B Relative to Baseline[a]
for the Bleached Papergrade Kraft and Soda Subcategory

	Option A[b]	Option B[b]
Reduction in Wood Consumption	Up to 0.3% Marginal reduction from screen room closure and spill recovery	Up to 0.3% Marginal reduction from screen room closure and spill recovery
Water Conservation	Typically 5 to 10% due to closed screening, better spill collection	Typically 10 to 15% due to closed screening, better spill collection, other mill modernization
Solid Waste Generation[c] Primary sludge	About 4% reduction due to fiber recovery	About 4% reduction due to fiber recovery
Secondary sludge at mills with activated sludge treatment	2% reduction due to reduced BOD_5 to treatment	3% reduction due to reduced BOD_5 to treatment
Energy Consumption (as change in bbls of oil)	Increase 1% due to energy for off-site chemical manufacture, with offsets in mill.	Decrease 1% due to replacement of Cl_2 and ClO_2 with O_2; reduction in WWTP power
Air Emissions From burning increased quantities of black liquor		
Total gaseous HAPs, kkg/yr	Increase 220 (1.1%)	Increase 308 (1.6%)
Total particulate HAPs, kkg/yr	Increase 0.71 (1.1%)	Increase 1.03 (1.6%)
Carbon monoxide, kkg/yr	Increase 1,440 (1.2%)	Increase 2,120 (1.7%)
Sulfur dioxide, kkg/yr	Increase 784 (1.2%)	Increase 1,150 (1.7%)
From changes in energy consumption		
Carbon dioxide, kkg/yr	Increase 154,000	Decrease 1,650,000
Sulfur dioxide, kkg/yr	Increase 1,800	Decrease 6,300
Total particulate HAPs, kkg/yr	Increase 4.64	Decrease 16.3
From changes in chlorine dioxide bleaching Carbon monoxide, kkg/yr	Increase 1500	Increase 220

[a]Baseline is technology in place as of mid-1995.
[b]Data presented are simplified. Refer to detailed discussion in body of report. Individual mills vary.
[c]Percentage reductions for solid waste are all shown relative to total solid waste discharge from same source in late 1980s.

Table 11-2

Bleach Plant Effluent Flow for Bleached Papergrade Kraft and Soda Mills With and Without Extended Delignification

	Hardwood[a]	Softwood[a]
Mills without oxygen delignification or extended cooking	24.7 m³/kkg	37.1 m³/kkg
Mills with oxygen delignification or extended cooking	19.7 m³/kkg	24.7 m³/kkg
Reduction in effluent flow	5 m³/kkg	12.4 m³/kkg

[a]DCN 13952, Section 24.

Table 11-3

Black Liquor Solids, BOD$_5$, and Sludge Generation for Option A and Option B for the Bleached Papergrade Kraft and Soda Subcategory

	Option A	% Change from Baseline Option A	Option B[a]	% Change from Baseline Option B
Additional heat from black liquor solids combustion[b] (GJ/d)	29,600	NC	45,600	NC
Additional BLS to combustion resulting from process changes[c] (kkg/d)	2,160	1.5	3,260	2.2
Decreased BOD$_5$ to treatment (kg/d)	649,000	21	979,000	31
Decreased sludge generation in ASTs (kkg/yr)	36,000	2	62,000	3

[a]Heat in BLS from extended delignification assumed to have HHV of 14.5 MJ/kg.
[b]See BAT Cost Model Support Document (4).
[c]Increase over baseline estimated assuming 1,750 kg BLS/kkg pulp for baseline.
NC = Not calculated.

Table 11-4

Effect of Options A and B on Energy Consumption Relative to 1995 Base Case for the Bleached Papergrade Kraft and Soda Subcategory

		Option A	Option B	Note
Electrical Power Consumption				
Increase (decrease) in off-site power consumption	MW	87	(161)	a
Increase (decrease) in on-site power consumption	MW	(21)	66	
Total increase (decrease) in power consumption	MW	67	(95)	
Total increase (decrease) in power consumption	kWh/kkg	19	(27)	
Increase (decrease) in thermal energy to generate power	GJ/d	23,100	(32,800)	b
Increase (decrease) in thermal energy to generate power	GJ/kkg	0.28	(0.39)	
Increase (decrease) in oil equivalent to generate power	trillion BTU/yr	7.666	(10.88)	
Increase (decrease) in oil equivalent to generate power	bbl/yr	1,347,000	(1,911,000)	
Steam Consumption				
Net steam requirements (savings)	kkg/d	(2,410)	1,790	
Fossil fuel requirement (savings) from steam demand (generation)	bbl/yr	(506,200)	376,400	c
Total Energy Consumption				
Total increase (decrease) in fuel consumed	**trillion BTU/yr**	**4.785**	**(8.734)**	**e**
Total increase (decrease) in fuel consumed	**bbl/yr**	**840,700**	**(1,535,000)**	**e**
Total increase (decrease) in fuel consumed	**number of households**	**46,100**	**(84,300)**	**d**
Increase (decrease) in fuel consumed relative to total energy consumption by bleached kraft subcategory in 1995		1%	(1%)	e

[a]Off-site power consumption is for manufacture of bleaching chemicals.
[b]Estimate of thermal energy required assumes overall efficiency of condensing power station and distribution system of 25 percent.
[c]Conversion of fuel oil to useful steam assumes overall steam plant efficiency of 75 percent.
[d]Assumes 103.6 million Btu/household/yr (Energy Information Administration (DOE) 1993)
[e]See DCN 14510 for baseline energy calculations of 116 million bbl/yr.

Table 11-5

Process Changes Affecting Energy Consumption at
Bleached Papergrade Kraft and Soda Mills

Process modification	Steam demand	Electrical demand
Improve brown stock washing and screen room closure	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor. Reduced demand from reduction in water to evaporate.	Minor, may be plus or minus.
Extended cooking	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor.	Insignificant in fiber line. Net reduction in off-site power for bleach chemical manufacture.
Oxygen delignification	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor. Heat demand for oxygen reactor.	Additional mixing energy in fiberline. Net reduction in power for bleach chemical manufacture.
High chlorine dioxide substitution	Minor increase	Increased energy for pulp mixing. Increased energy off site for bleach chemical manufacture.
Best Management Practices	Reduced demand for fossil fuel corresponding to fuel value of recovered black liquor. Steam demand to evaporate recovered water.	Insignificant
Evaporator upgrade	Steam demand increase	Insignificant
Evaporator load reduction	Steam demand decrease	Insignificant
Measures to compensate for increased load on recovery boiler:		
` Recovery boiler upgrade	Steam generated from above mentioned black liquor replaces some steam from fossil fuel.	Minor change
` Anthraquinone pulping additive	None	None
` Black liquor oxidation	Reduction in net demand since steam generated in reaction is used for evaporator.	Increase
Recausticizing upgrade	Insignificant	Minor change
Reduction in effluent flow due to above	None	Minor reduction in pumping energy.
Reduction in effluent BOD_5 due to above	None	Reduction in WWTP power.

Table 11-6

Impact of BAT, PSES, and BMPs:
Bleached Papergrade Kraft and Soda Subcategory Air Emissions

Air Pollutants	Bleached Papergrade Kraft BAT Baseline Emissions and Reductions (Mg/yr)		
	Baseline Emissions	Emission Reductions from BAT/PSES/BMPs	Emission Reductions from BAT/PSES/BMPs Plus MACT I, II, and III
Hazardous air pollutants (HAP)	149,000	10,000	89,800
Chloroform[a]	9,510	6,060	6,240
Methanol[a]	96,400	3,100	66,080
Volatile organic compounds	569,000	11,000	301,200
Total reduced sulfur	100,000	1,300	59,800

[a]Baseline emission is a subset of baseline HAP emissions (149,000 Mg/yr).

Table 11-7

Atmospheric Emission Changes Due to Burning Recovered Black Liquor, Bleached Papergrade Kraft and Soda Subcategory Before MACT II is Applied

Pollutant	Emissions, Mg/yr[a]			Change from Baseline	
	Before MACT II Baseline	Increase from Option A	Increase from Option B	Option A	Option B
Total Reduced Sulfur (TRS)	2,650	27.4	36.0	1.03%	1.36%
Criteria Pollutants					
Carbon Monoxide	123,700	1,440	2,120	1.17%	1.71%
Particulate Matter	31,370	356	514	1.14%	1.64%
Nitrogen Oxides	36,120	423	623	1.17%	1.73%
Sulfur Dioxides	67,770	784	1,150	1.16%	1.69%
Volatile Organic Compounds	19,500	213	295	1.09%	1.51%
Gaseous HAPs					
Acetaldehyde	1,150	12.5	17.0	1.08%	1.48%
Benzene	580	6.43	9.10	1.11%	1.57%
Formaldehyde	421	4.99	7.43	1.19%	1.76%
Hydrochloric Acid	6,890	79.1	115	1.15%	1.67%
Methanol	6,810	72.5	95.9	1.06%	1.41%
Methyl Ethyl Ketone	469	5.26	7.45	1.12%	1.59%
Methyl Isobutyl Ketone	556	6.26	8.91	1.13%	1.60%
Phenol	1,330	14.6	20.4	1.09%	1.53%
Toluene	482	5.45	7.79	1.13%	1.62%
Xylenes	1,159	13.0	18.5	1.12%	1.60%
Total Gaseous HAPs	19,860	220	308	1.11%	1.55%

Table 11-7 (Continued)

Pollutant	Emissions, Mg/yr[a]			Change from Baseline	
	Before MACT II Baseline	Increase from Option A	Increase from Option B	Option A	Option B
Particulate HAPs					
Antimony	2.72	0.02	0.03	0.89%	1.29%
Arsenic	8.16	0.10	0.14	1.17%	1.69%
Beryllium	0	0.00	0.00	0.00%	0.00%
Cadmium	1.81	0.02	0.02	0.86%	1.25%
Chromium	2.72	0.02	0.03	0.89%	1.29%
Cobalt	1.81	0.02	0.03	1.14%	1.65%
Lead	20.0	0.22	0.32	1.13%	1.62%
Manganese	11.8	0.14	0.20	1.16%	1.67%
Mercury	0.907	0.01	0.02	1.49%	2.15%
Nickel	5.44	0.06	0.08	1.05%	1.51%
Selenium	8.16	0.10	0.14	1.20%	1.73%
Total Particulate HAPs	62.6	0.71	1.03	1.14%	1.64%
Total HAPs[b]	19,920	220	308	1.11%	1.55%

[a]All nationwide baseline emissions estimates received from MRI (MRI July 1996, October 1996) (21,29)
[b]Total HAPs include gaseous HAPs and particulate HAPs.

Table 11-8

Atmospheric Emission Changes Due to Burning Recovered Black Liquor, Bleached Papergrade Kraft and Soda Subcategory After MACT II is Applied

Pollutant	Emissions, Mg/yr[a]			Change from Baseline	
	After MACT II Baseline	Increase from Option A	Increase from Option B	Option A	Option B
Total Reduced Sulfur (TRS)	2,650	27.4	36.0	1.03%	1.36%
Criteria Pollutants					
Carbon Monoxide	123,700	1,440	2,120	1.17%	1.71%
Particulate Matter	18,500	209	301	1.13%	1.62%
Nitrogen Oxides	36,120	423	623	1.17%	1.73%
Sulfur Dioxides	67,770	784	1,150	1.16%	1.69%
Volatile Organic Compounds	19,500	213	295	1.09%	1.51%
Gaseous HAPs					
Acetaldehyde	1,150	12.5	17.0	1.08%	1.48%
Benzene	580	6.43	9.10	1.11%	1.57%
Formaldehyde	421	4.99	7.43	1.19%	1.76%
Hydrochloric Acid	6,890	79.1	115	1.15%	1.67%
Methanol	6,810	72.5	95.9	1.06%	1.41%
Methyl Ethyl Ketone	469	5.26	7.45	1.12%	1.59%
Methyl Isobutyl Ketone	556	6.26	8.91	1.13%	1.60%
Phenol	1,330	14.6	20.4	1.09%	1.53%
Toluene	482	5.45	7.79	1.13%	1.62%
Xylenes	1,159	13.0	18.5	1.12%	1.60%
Total Gaseous HAPs	19,860	220	308	1.11%	1.55%

Table 11-8 (Continued)

Pollutant	Emissions, Mg/yr[a]			Change from Baseline	
	After MACT II Baseline	Increase from Option A	Increase from Option B	Option A	Option B
Particulate HAPs					
Antimony	0.91	0.01	0.02	1.57%	2.25%
Arsenic	5.44	0.06	0.08	1.03%	1.48%
Beryllium	0.00	0.00	0.00	0.00%	0.00%
Cadmium	0.91	0.01	0.01	1.02%	1.46%
Chromium	0.91	0.01	0.02	1.57%	2.25%
Cobalt	0.91	0.01	0.02	1.34%	1.92%
Lead	11.8	0.13	0.19	1.12%	1.61%
Manganese	7.3	0.08	0.12	1.11%	1.59%
Mercury	0.00	0.01	0.01	0.00%	0.00%
Nickel	2.72	0.03	0.05	1.23%	1.77%
Selenium	5.44	0.06	0.08	1.05%	1.51%
Total Particulate HAPs	37.2	0.42	0.60	1.13%	1.62%
Total HAPs[b]	19,890	220	308	1.11%	1.55%

[a]All nationwide baseline emissions estimates received from MRI (MRI July 1996, October 1996) (21,29)
[b]Total HAPs include gaseous HAPs and particulate HAPs.

Table 11-9

Atmospheric Emissions: Oil Combustion and Oil Combustion Plus BLS Combustion (Before MACT II is Applied) (Mg/yr)

Pollutant[a]	Oil Combustion[b]		Combustion: Total Oil Plus BLS	
	Increase for Option A	Decrease for Option B	Increase for Option A	Decrease for Option B
Criteria Pollutants				
Sulfur Dioxides[c]	1,794	6,312	2,578	5,166
Particulate HAPs				
Antimony	0.08	0.27	0.10	0.24
Arsenic	0.14	0.51	0.24	0.37
Beryllium	0.009	0.032	0.009	0.03
Cadmium	0.25	0.87	0.27	0.85
Chromium	0.16	0.57	0.18	0.54
Cobalt	0.21	0.74	0.23	0.71
Lead	0.23	0.82	0.45	0.50
Manganese	0.10	0.36	0.24	0.16
Mercury	0.04	0.13	0.05	0.11
Nickel	3.3	11.8	3.36	11.7
Selenium	0.08	0.28	0.18	0.14
Total Particulate HAPs	**4.64**	**16.32**	**5.35**	**15.29**

[a]Emissions based on energy consumption in Figure 11-1, Values shown are total kkg/yr for the bleached papergrade kraft and soda subcategory.
[b]Emission factors from AP-42, Section 1.3, 5th Edition, 1995.
[c]Assumes that the average sulfur content of residual oil burned in the US is 0.7 percent (or where high sulfur oil is used, SO_2 emission control equipment is installed to reduce emissions to the equivalent of 0.7 percent sulfur oil).

Table 11-10

Changes to Carbon Dioxide Emissions Resulting From Changes in Consumption of Fossil Fuel and Wood Consumption for Option A and Option B for the Bleached Papergrade Kraft and Soda Subcategory

	Fossil Fuel Consumption	Wood Consumption	Net Change
Option A	Increase by 399,000 kkg/yr	Reduce by 245,000 kkg/yr	Increase by 154,000 kkg/yr
Option B	Reduce by 1,405,000 kkg/yr	Reduce by 245,000 kkg/yr	Reduce by 1,650,000 kkg/yr

Table 11-11

Average CO Emissions From Kraft Bleaching With Chlorine Dioxide

Mill Code	Bleaching Sequence	Wood Type	% Sub.	Total ClO2 charge	Bleach Plant Inlet Kappa	OD or EC	Total CO Emissions g/kkg			Source of Data
							Avg.	Min.	Max.	
SF1	Cd (Eop)DEpD	Hwd	6%	0.74%	8.0	y	268	250	295	Mill
SD2	CD(Eo) DP	Swd	15%	1.08%	11.3	y	264	241	282	Mill
SE1	D(Eop)DP	Swd	100%	1.12%	13.3	y	295	214	345	Mill
C	D(Eop)D	Swd	100%	1.18%	15.0	y	282	136	395	NCASI
C	D(Eop)D	Hwd	100%	1.20%	10.0	y	400	309	550	NCASI
AA	CdEDED	Swd	0%	1.30%	30.0	n	332			Lab
SE2	D(Eo)DP	Hwd	100%	1.32%	8.2	y	286	264	309	Mill
C	D(Eop)D	Swd	100%	1.43%	12.5	y	423	327	495	NCASI
AA	CdEDED	Swd	10%	1.53%	30.0	n	314			Lab
SF2	Cd (Eop)DEpD	Swd	13%	1.58%	13.0	y	586	550	623	Mill
SA1	Cd(Eo) D	Hwd	35%	1.65%	9.0	y	245		295	Mill
SA2	CD(Eo)D	Swd	55%	1.66%	11.3	y	195		218	Mill
SD1	Cd(Eo) D	Swd	50%	1.97%	10.9	y	355	350	364	Mill
AA	CdEDED	Swd	30%	1.98%	30.0	n	323			Lab
SG2	CEDED	Swd	30%	2.02%	nk	n	532	459	564	Mill
E	Cd(Eop)DED	Swd	60%	2.14%	27.5	n	323	264	409	NCASI
E	Cd(Eop)DED	Swd	60%	2.19%	27.5	n	309	218	414	NCASI
AA	CdEDED	Swd	50%	2.44%	30.0	n	364			Lab
SG1	CEDED	Swd	15%	2.49%	nk	n	650	641	236	Mill
B	D(Eop)D	Swd	100%	2.67%	27.0	n	386	223	614	NCASI
G	D(Eop) PD	H/S/Swdust	100%	2.77%	22.5	n	423	245	527	NCASI
B	D(Eop)D	Swd	100%	2.82%	27.0	n	432	91	750	NCASI
AA	CdEDED	Swd	70%	2.90%	30.0	n	441			Lab
F	Cd(Eop) D	Swd	85%	3.06%	27.0	n	455	286	627	NCASI

Table 11-11 (Continued)

Mill Code	Bleaching Sequence	Wood Type	% Sub.	Total ClO2 charge	Bleach Plant Inlet Kappa	OD or EC	Total CO Emissions g/kkg			Source of Data
							Avg.	Min.	Max.	
B	D(Eop)D	Hwd	100%	3.07%	17.0	n	295	195	423	NCASI
G	D(Eop) PD	Swd	100%	3.39%	30.0	n	464	414	550	NCASI
SB	D Eop DD	Swd	100%	3.41%	13.0	y	414	409	418	Mill
AA	DEDED	Swd	100%	3.58%	30.0	n	527			Lab
SG3	CEDED	Swd	70%	3.63%	nk	n	614	577	650	Mill
SG4	CEDED	Swd	100%	3.98%	nk	n	568	568	568	Mill
						Maximum	650	641	750	
						Minimum	195	91	218	
						Average	392	329	455	

Data in column "OD or EC" were inferred by EPA from bleaching conditions. All other data after Someshwar (1997) (23).

Table 11-12

**Carbon Monoxide Emissions from Bleach Plants for Option A and Option B
for Bleached Papergrade Kraft and Soda Subcategory**

	Baseline	Option A	Option B
Chlorine dioxide use, kkg/day	1,660	2,200	1,740
Carbon monoxide emissions, kkg/yr	10,900	12,400	11,200
Carbon monoxide emissions, g/kkg pulp	374	425	381

Table 11-13

Comparison of NSPS/PSNS to Conventional Technology

	1000 tpd Fiber Line
Wood Consumption	No Difference
Effluent Flow	Moderate Decrease[a]
BOD$_5$ to Treatment	Decrease by 11,300 kg/day
Sludge Generation	Decrease by 890 kg/day
Carbon Dioxide Emissions	Decrease by 21,700 Mg/yr
Energy Impacts:	
Total Electricity Demand	Decrease by 222,600 million BTU/yr in oil equivalent
Total Steam Demand	Increase by 60,180 million BTU/yr in oil equivalent
Total Energy Demand	Decrease by 162,400 million BTU/yr in oil equivalent
Air Emissions:	
Hazardous Air Pollutants	Increase by 407 Mg/yr
Chloroform	No Difference
Volatile Organic Compounds	Increase by 707 Mg/yr
Total Reduced Sulfur	Increase by 28 Mg/yr
Particulate Matter	Decrease by 12 kg/yr
Carbon Monoxide	Decrease by 3 Mg/yr
Nitrogen Oxides	Decrease by 28 Mg/yr
Sulfur Dioxides	Decrease by 56 Mg/yr

[a]See Section 11.4.1.3

Table 11-14
Comparison of Two TCF Technologies to Conventional Technology
(Option A) for the Bleached Papergrade Kraft and Soda Subcategory

	TCF-Peroxide	TCF-Ozone
Wood Consumption	No Difference	No Difference
Final Effluent Flow	Decrease by approximately 90 percent (a)	Decrease by approximately 90 percent (a)
BOD$_5$ to Treatment	Decrease by approximately 90 percent (a)	Decrease by approximately 90 percent (a)
Sludge Generation from BOD$_5$	Decrease by approximately 90 percent (a)	Decrease by approximately 90 percent (a)
Carbon Dioxide Emissions	Moderate Decrease	Moderate Decrease
Energy Impacts:		
Total Electricity	Decrease by 4.73 trillion BTU/yr in oil equivalent	Decrease by 7.11 trillion BTU/yr in oil equivalent
Total Steam Demand	Decrease by 35.1 trillion BTU/yr in oil equivalent	Decrease by 83.8 trillion BTU/yr in oil equivalent
Total Energy Demand	Decrease by 39.9 trillion BTU/yr in oil equivalent	Decrease by 90.9 trillion BTU/yr in oil equivalent
Air Emissions:		
Hazardous Air Pollutants - Chlorinated	Elimination (b)	Elimination (b)
Hazardous Air Pollutants - Non-Chlorinated	No Difference (c)	No Difference (c)
Chloroform	Elimination (b)	Elimination (b)
Volatile Organic Compounds - Chlorinated	Elimination (b)	Elimination (b)
Volatile Organic Compounds - Non-Chlorinated	No Difference (c)	No Difference (c)
Total Reduced Sulfur	No Difference	No Difference
Particulate Matter	No Difference	No Difference
Carbon Monoxide from ClO$_2$ Application	Elimination	Elimination

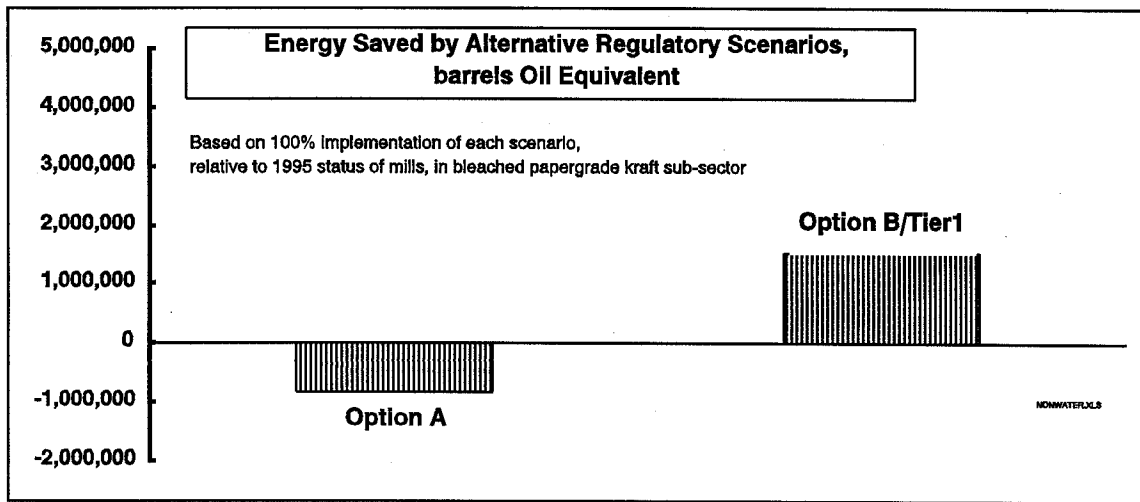## Table 11-14 (Continued)

	TCF-Peroxide	TCF-Ozone
Nitrogen Oxides	Slight Decrease (d)	Slight Decrease (d)
Sulfur Dioxides	Slight Decrease (d)	Slight Decrease (d)

(a) Final effluent flow rates are typically 95 m3/kkg (see Section 11.3), of which 25 to 60 m3/kkg typically come from bleach plant effluents. While TCF operation itself does not require recycling of bleach plant effluents, TCF facilities operating today typically have bleach plant effluent discharges of 5 to 15 m3/kkg, a bleach plant reduction of approximately 30 m3/kkg (30). TCF facilities recycle bleach plant effluents to recover bleaching chemicals and to reduce BOD_5 load to and sludge generation in secondary treatment. Industry practice in mills using TCF technology is to reduce effluent flow throughout the mill. For example, the Metsa-Rauma mill at Rauma, Finland discharges 9 m3/kkg effluent, of which 5 m3/kkg is from the bleach plant (31). 90 percent final effluent flow reduction is attainable but actual reduction at each mill depends on local site constraints and the priority given to flow reduction. It is reasonable to assume that comparable decreases would occur for BOD_5 and sludge generation from BOD_5.
(b) Any emission results from process water chlorination.
(c) See Revised Draft Chemical Pulping Emission Factor Development Document, DCN A9240IVA8.
(d) Due to decrease in fossil fuel consumption.

Energy Saved by Alternative Regulatory Scenarios, barrels Oil Equivalent

Based on 100% Implementation of each scenario, relative to 1995 status of mills, in bleached papergrade kraft sub-sector

Option B/Tier1

Option A

NONWATER.XLS

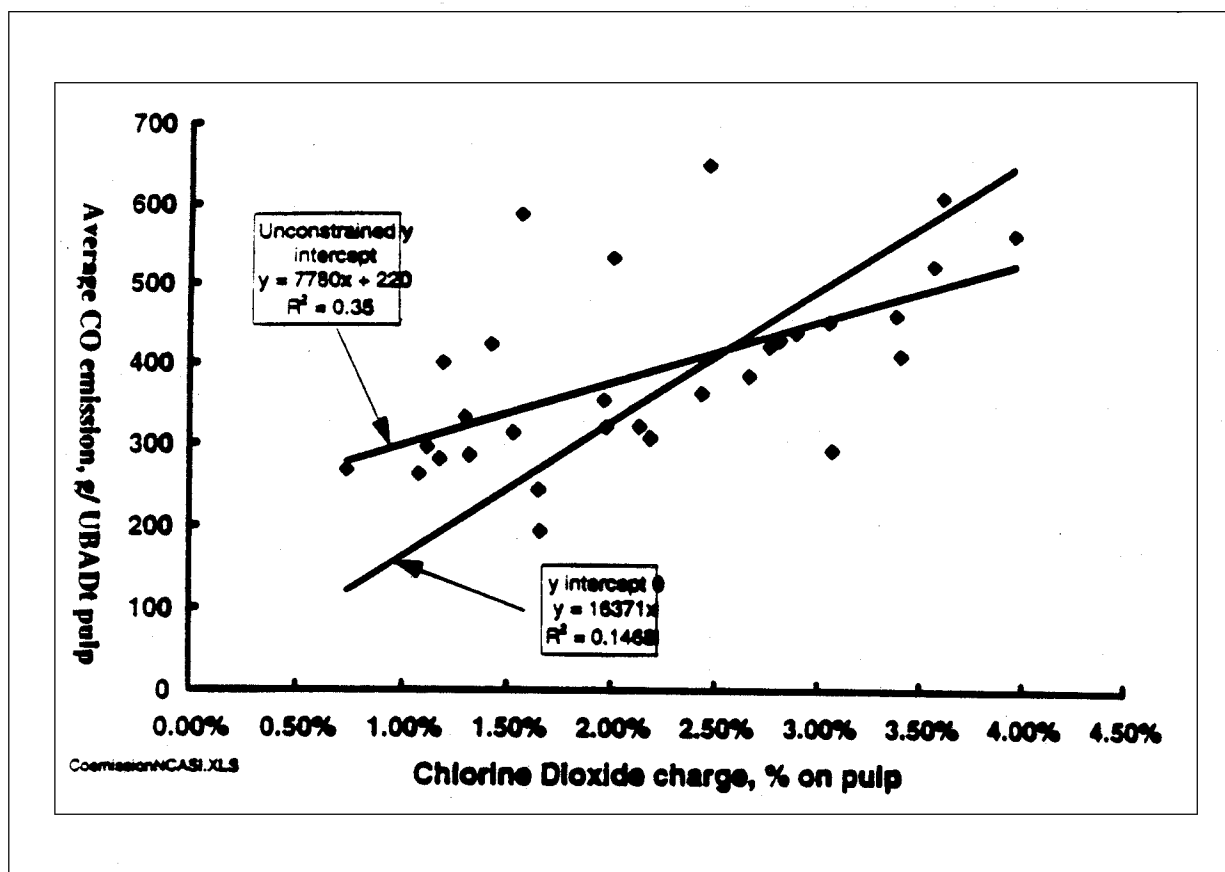**Figure 11-1. Energy Impacts of Proposed Regulations, Bleached Papergrade Kraft and Soda Subcategory**

Figure 11-2. Emissions of CO Measured by NCASI

SECTION 12

BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

12.1   Introduction

The 1977 amendments to the Clean Water Act established BCT for discharges of conventional pollutants from existing industrial point sources. BCT is not an additional limitation, but replaces BAT for the control of conventional pollutants.

This section presents a summary of the final BCT methodology, describes the revisions made to the BCT technology options and cost estimates for the end-of-pipe treatment technologies, and discusses the results of the final BCT cost test. This section does not represent the methodology used to estimate end-of-pipe treatment costs since it has not changed since proposal. This methodology is described in the Proposed Technical Development Document (EPA 821-R-93-019) (TDD).

12.2   Summary of the Final BCT Methodology

In considering whether to promulgate revised BCT limits for the Bleached Papergrade Kraft and Soda (Subpart B) and the Papergrade Sulfite (Subpart E) subcategories, EPA considered whether technologies are available that achieve greater removals of conventional pollutants than the current BPT effluent limitations guidelines. EPA also considered whether those technologies are cost-reasonable according to the BCT cost test, which compares the incremental removals and costs associated with BCT limitations to a baseline associated with BPT.

For the final rule, EPA chose to conduct the BCT analysis using estimates of industry's 1989 discharge of conventional pollutants (based on data from the 1990 industry census) as the BPT baseline against which BCT technology options are analyzed. EPA evaluated the candidate BCT technologies and concluded that none of the options passed the BCT cost test. Therefore, at this time, EPA is not promulgating more stringent BCT limitations for Subparts B and E of this industry category. BCT limitations for former Subparts G, H, I, and P (now Subpart B) and former Subparts J and U (now Subpart E) remain in effect.

12.3   Revisions to the Proposed BCT Technology Options and Cost Estimates

Based on comments received on the proposed rule and the July 15, 1996 Notice of Data Availability (61 FR 36835) and correction of double-counting some costs, EPA revised the inputs to the BCT cost test related to BCT option performance, the costs to install or upgrade end-of-pipe treatment systems, and the annual operating costs for end-of-pipe treatment systems. This section describes only these revisions (see also Comment Response Document, DCN 14497, Volume IV, "BCT Cost Test").

12.3.1   Conventional Pollutant Control Option Performance

At proposal, EPA developed four candidate BCT options:

(1)   Option A.1 - Performance level of the best-performing mill in each subcategory assuming the baseline performance is equal to the proposed BPT Option 2;

(2)   Option A.2 - Multimedia filtration assuming the baseline performance is equal to the proposed BPT Option 2;

(3)   Option B.1 - Performance level representing the average of the best 90 percent of mills in each subcategory assuming the baseline performance is equal to current industry performance;

(4)   Option B.2 - Performance level representing the average of the best 50 percent of mills in each subcategory assuming the baseline performance is equal to current industry performance.

Two of these options, Options A.1 and A.2, assumed the baseline performance to be equal to the proposed BPT Option 2. Because EPA has decided not to revise BPT limitations for conventional pollutants, EPA chose not to evaluate these two options. For the final rule for the Bleached Papergrade Kraft and Soda Subcategory, EPA only considered Options B.1 and B.2, known now simply as BCT Options 1 and 2.

EPA identified a new BCT option for the Papergrade Sulfite Subcategory, which is the average performance level achieved by the three mills with at least 85 percent of their production in the subcategory whose wastewater treatment performance reflects BCT candidate level performance. Final production of most mills in the Papergrade Sulfite Subcategory is comprised of a large portion of purchased pulp. For the proposed rule, BCT option performance levels for this subcategory were calculated using data from mills with 37 to 96 percent of their final production in the subcategory. After proposal, EPA reassessed the impact of purchased pulp on the final effluent BOD_5 load and determined that four mills with 85 percent or more of final off-machine production derived from sulfite pulp produced on site discharged substantially higher BOD_5 loads from secondary biological wastewater treatment. EPA determined that effluent from these few mills more appropriately represented wastewater from the subcategory. EPA used data from three of these mills to characterize BCT, because EPA did not consider the treatment performance of the fourth mill to be representative of the subcategory as a whole. This fourth mill treats wastewater from liquor by-products manufactured on site, which is unique among papergrade sulfite mills.

Section 8.3 of this document presents a detailed discussion of the development of options for the control of conventional pollutant discharges.

12.3.2   Accounting for Cluster Rules Impacts on BCT Costs

In order to conduct the BCT cost test, discussed in Section 12.4.4. EPA estimated the pollutant removals achieved by the industry in upgrading from BPT to BCT. EPA also estimated the cost for upgrading from BPT to BCT.

EPA estimated the pollutant removals achieved by the BCT Options by calculating the reduction in each mills discharged pollutant load at Options 1 and 2, relative to the baseline (pollutant load discharged in 1989, as reported in the 1990 industry census). At proposal, EPA attributed the entire increment to BCT, even though some conventional pollutant removals result from other components of the Cluster Rules.

EPA estimated the cost for each mill to upgrade its treatment system from the baseline 1989 performance to the Option 1 and Option 2 level of performance. Before EPA estimated the costs of BPT at proposal it accounted for the pollutant load reduction that will result from implementation of the cluster rules (i.e., BAT, BMP, and NESHAP). Applying these load reductions reduced the load of BOD_5 requiring treatment, and therefore also reduced the costs associated with end-of-pipe treatment system upgrades. At proposal, EPA used these BPT costs to represent the costs of BCT Options B.1 and B.2.

EPA received comments questioning this approach. When EPA revised the inputs to the BCT cost test, it reevaluated this approach and, for the final rule, decided not to account for cluster rule impacts on costs because they were not also taken into account when estimating loads.

12.3.3   Engineering Cost Estimates

EPA received several comments pertaining to the estimate of costs to install and/or upgrade end-of-pipe treatment systems for the removal of conventional pollutants. The Agency has not changed its approach to designing end-of-pipe treatment systems, but has revised certain unit costs which comprise the capital and annual operating and maintenance costs for end-of-pipe treatment and some assumptions based on comments received on the proposed rule. This section presents a summary of the individual unit costs and assumptions that were revised or reevaluated prior to their inclusion in the final BCT cost test, including aerated stabilization basin liner costs, activated sludge aeration and sludge handling costs, flow reduction costs, indirect cost factors, land costs, and polymer addition. All other costs that comprise end-of-pipe treatment system installation and operation have been described previously in the TDD supporting the proposed rule.

12.3.3.1   Aerated Stabilization Basin Liner Costs

Based on comments received on the proposed rule, EPA reevaluated the unit cost to install liners for aerated stabilization basins. At proposal, EPA estimated clay liner costs to be $0.37 per square foot (1991 dollars). Commenters questioned whether these costs accounted for

transportation of the clay to mills that were not located near a vendor. Therefore, EPA reevaluated the transportation costs associated with installing clay liners and found that, in some cases, transportation would add over $2.00 per square foot to the cost of installing clay liners.

Because of the relatively high clay transportation costs, EPA investigated alternative materials for use as aerated stabilization basin liners, including plastic (HDPE) liners and geosynthetic liners. Based on the information provided by vendors, HDPE liners would cost approximately $0.35 per square foot, including transportation and installation, while geosynthetic liners would cost $0.57 per square foot, including transportation and installation. EPA chose to estimate basin costs assuming installation of a geosynthetic liner, which includes excavating the lagoon, laying the liner, and covering the liner with 6 to 8 inches of backfill from the original excavation.

12.3.3.2   Activated Sludge Aeration Costs

EPA reevaluated aeration costs for mills with existing activated sludge systems. When designing upgrades to achieve the target BOD_5 and TSS loads, EPA considered additional aeration tank volume and/or aeration, as well as operational modifications. In some cases, EPA determined that the mill has sufficient existing aeration capacity, but requires additional retention time to meet the target long-term average conventional pollutant concentrations. In these cases, additional aeration costs were eliminated from the compliance cost estimates.

12.3.3.3   Activated Sludge Handling Costs

As described in the TDD, EPA estimated costs for the management and disposal of sludge from new or upgraded activated sludge units. These incremental costs were based on the increased amounts of sludge resulting from upgrades as determined by the activated sludge design model.

At proposal, the Agency calculated mill-specific unit costs to estimate the capital and annual operating and maintenance (O&M) costs for sludge handling and disposal. EPA assumed that sludge increases of 5 percent or less could be handled with no additional cost. Following proposal, EPA determined that sludge increases up to 15 percent could be handled with no additional cost. However, EPA also determined that, for mills that required increased sludge handling capacity, a minimum capital cost would be incurred that was greater, in some cases, than the incremental capital cost that was previously estimated.

12.3.3.4   Flow Reduction Costs

As described in Section 11.6.1.1 of the TDD, some mills could not achieve target BOD_5 or TSS loads for the candidate BCT options with end-of-pipe treatment alone because their target BOD_5 and TSS concentrations were lower than the lowest currently demonstrated concentrations. Therefore, as at proposal, these mills required flow reduction to increase their

target concentrations. The technologies that reduce flow also reduce BOD_5 and TSS loads. Flow reduction, if required, was applied to a mill first; the revised final effluent flow rates, BOD_5 load, and TSS load achieved with flow reduction were entered into models to design and cost end-of-pipe wastewater treatment upgrades that would enable the mill to achieve the target loads.

For some mills, the cost to meet the more stringent candidate BCT option (Option 2) was lower than the cost to meet Option 1 because Option 1 costs were based on end-of-pipe treatment upgrades only and not on flow reduction. For these mills, EPA decided for the final rule to cost flow reduction for both candidate BCT options, which resulted in a lower cost to comply with BCT Option 1.

12.3.3.5   Indirect Cost Factors

In response to comments, EPA reviewed the indirect cost factors used to estimate overhead and profit, engineering, and contingency costs. The indirect cost factors used at proposal totaled 30 percent of the total direct capital costs. Commenters believed that indirect costs could range from 39 percent to 85 percent of the total direct capital costs. EPA reviewed data submitted by commenters and consulted a standard chemical engineering design text. (1) EPA found that an indirect cost factor of 30 percent was reasonable for the final design stage; however, an indirect cost factor of 45 percent was more appropriate for cost estimates at the conceptual stage. Therefore, because EPA's costs are "conceptual design" not "final design" EPA revised the end-of-pipe compliance costs using an indirect cost factor of 45 percent.

12.3.3.6   Land Costs

While in the process of revising end-of-pipe cost estimates, EPA considered whether certain mills actually required additional capital costs to purchase land on which to build or expand end-of-pipe treatment systems. For certain mills for which EPA had estimated land purchase costs at proposal, EPA reviewed information collected during recent site visits. Although this information suggested these mills may have sufficient room to accommodate the estimated treatment upgrades, because this information contradicted information reported in the 1990 Census Questionnaire and similar information was not available for all mills, for the final rule, EPA chose not to revise (i.e., reduce) land purchase costs. The result is more conservative (i.e., higher) compliance cost estimates.

12.3.3.7   Polymer Addition

At proposal, the polymer addition upgrade was developed based on best professional judgment. As discussed in the Proposed TDD, polymer addition was costed at a rate of 5 mg/L based on final effluent flow rate. Comments received on the proposal from pulp mills stated that EPA had overcosted polymer addition by using too high a rate of addition. EPA contacted additional pulp mills and determined that a polymer addition rate of 1.1 mg/L was more appropriate. Therefore, EPA revised the cost of polymer addition, which resulted in lower compliance costs.

12.3.3.8   Calculation of Total Annualized Costs

One of the components of total annualized costs for both the proposed and final rulemakings is annual general and administrative costs (GAC), such as insurance, which is included in annual O&M costs. For proposal, EPA estimated GAC as 4 percent of capital costs plus 60 percent of O&M costs for purposes of determining BCT-candidate option costs. After proposal, EPA determined that the 60 percent component was already included in the engineering estimates. For the final rule, therefore, EPA estimated GAC for BCT-candidate option costs as only 4 percent of capital. (For more discussion of their impact on this change see, Comment Response Document, DCN 14497, Volume IV, "BCT Cost Test.")

12.4   Final BCT Methodology

Components of the BCT methodology used for EPA's final evaluation of BCT Options 1 and 2 are described in the following sections.

12.4.1   BCT Technology Basis

As discussed in Section 12.2.1, EPA identified two final candidate BCT options for the Bleached Papergrade Kraft and Soda Subcategory and one final candidate BCT option for the Papergrade Sulfite Subcategory. As at proposal, EPA calculated the BCT performance levels as a function of effluent pollutant concentration, mill production, and effluent flow rate. Both in-process flow reduction technologies and end-of-pipe wastewater treatment can be combined to achieve the BCT performance levels.

The technologies used to estimate the cost to comply with BCT Options 1 and 2 are the same technologies used at proposal. Technologies were selected based on the operations present at each mill, as reported in the 1990 census questionnaire. Costed technologies include:

> Flow reduction technologies
> `   Paper machine vacuum pump seal water recycle;
> `   Screen room closure; and/or
> `   Reuse of deinking washwater after flotation clarification.
>
> End-of-pipe wastewater treatment
> `   Primary clarification;
> `   Aerated stabilization basins; and/or
> `   Activated sludge systems.

12.4.2 End-of-Pipe Treatment Costs

The final BCT compliance cost estimates for the Bleached Papergrade Kraft and Soda (BPK) and the Papergrade Sulfite (PS) subcategories are shown in Table 12-1. EPA estimated that BPK mills would incur an average capital cost of $1.2 million (and a maximum cost of $14.5 million) for Option 1 and an average capital cost of $2 million (and a maximum cost of $17.4 million) for Option 2. Annual O&M costs for the two options ranged from zero to $3.5 million. PS mills would incur an average capital cost of $1.2 million (and a maximum cost of $3.9 million). Annual O&M costs ranged from zero to $0.3 million.

12.4.3 Conventional Pollutant Removals

The final BCT option conventional pollutant removals for the Bleached Papergrade Kraft and Soda and the Papergrade Sulfite subcategories are shown in Table 12-2. EPA estimated that BPK mills would remove an average of 1.6 million pounds of BOD_5 and TSS from pulp mill effluents for Option 1 and an average of 2.5 million pounds of BOD_5 and TSS for Option 2. PS mills would remove an average of 57,000 pounds of BOD_5 and TSS under the candidate option.

12.4.4 BCT Cost Test Results

The background, application, and results of the BCT cost test are discussed in the following sections.

12.4.4.1 Background

The 1977 Clean Water Act amendments added Section 304(b)(4), which established BCT for direct discharges of conventional pollutants from existing industrial point sources. Effluent limitations based on BCT may not be less stringent that the limitations based on BPT. Thus, BPT effluent limitations are a "floor" below which BCT effluent limitations cannot be established.

The Clean Water Act amendments that created BCT also specify that the cost associated with BCT effluent limitations be "reasonable" with respect to the effluent reductions. Accordingly, the BCT methodology was developed to answer the question of whether it is "cost-reasonable" for industry to control conventional pollutants at a level more stringent than that already required by BPT effluent limitations.

As promulgated in July 1986 (51 FR 24974), the first step in establishing BCT effluent limitations for an industry (or a subcategory within an industry) is to identify candidate technologies that provide conventional pollutant control beyond the level achieved by the BPT effluent limitations. The next step is to evaluate these technology options by applying the two-part BCT cost test. To "pass" the POTW test (the first part of the test), the cost per pound of conventional pollutant removed by industrial dischargers in upgrading from BPT to BCT must be

less than the cost per pound of conventional pollutant removed in upgrading POTWs from secondary treatment to advanced secondary treatment. The POTW upgrade cost is referred to as the POTW benchmark; its derivation is described in the 1986 final BCT methodology notice.

The second part of the test that the BCT technology must pass is the industry cost-effectiveness test. This test is actually a ratio of two incremental costs: (1) the cost per pound removed by the BCT technology relative to BPT; and (2) the cost per pound removed by BPT relative to no treatment (i.e., "raw" waste load or "baseline"). The ratio of these two costs is a measure of the BCT technology's cost effectiveness. As in the POTW test, this ratio is compared to a calculated industry cost benchmark. If the industry ratio is lower than the benchmark, the BCT technology passes the cost test.

EPA evaluates both tests as measures of reasonableness. As such, if the BCT technology passes both the POTW and industry cost test, than the most stringent technology option among them becomes the basis for setting BCT effluent limitations. Alternately, if no candidate technology more stringent than BPT passes, then BCT effluent limitations are set equal to BPT effluent limitations.

12.4.4.2   Application of the Final BCT Cost Test

EPA reviewed the control and treatment technology alternatives available for application in the pulp, paper, and paperboard industry for the control of conventional pollutants. As mentioned in Section 12.2.1, the result was to define two final candidate technologies for BPK mills and one final candidate technology for PS mills.

The BCT cost test calculations rely on cost and performance data from the 1990 industry census questionnaire and on results from the wastewater treatment model used at proposal (with the changes noted in Section 12.2.3). Since no information is available that accurately depicts the costs for the removal of conventional pollutants from raw waste load (RWL) to the current BPT regulation, the BCT cost test was performed using the LTA as derived from the 1989 performance data collected in the 1990 industry census questionnaire to represent BPT level of performance of biological treatment (biological treatment constitutes the basis of the current BPT). The source of cost estimates for wastewater treatment upgrades to achieve BCT was the end-of-pipe treatment system cost model used at proposal, which estimates capital and operating engineering costs. These costs were annualized using a cost annualization model that estimates the cost actually incurred by the mill to upgrade its pollution controls. This model takes into account tax savings the business accrues through depreciation and other tax shields.

Given these inputs, the BCT cost test was performed for two option for BPK mills and one option for PS mills:

> `   BPK - Option 1 - Current LTA to the average of the best performing 90 percent of BPK mills;

>> BPK - Option 2 - Current LTA to the average of the best performing 50 percent of BPK mills; and

>> PS Option - Current LTA to the average of PS mills.

For each option, the pounds of pollutant removed and cost incurred for the POTW cost test are the incremental pounds and costs associated with secondary wastewater treatment upgrades and necessary flow reduction. The ratio of incremental costs compared to incremental pounds constitutes the first part of the BCT cost test.

The second part, the industry cost-effectiveness test, requires the computation of a ratio of two incremental costs. The first incremental cost is the cost per pound for the removal of conventional pollutants incurred by industry in upgrading from BPT to BCT (i.e., the ratio from the first part of the cost test). The second incremental cost is the cost per pound for the removal of conventional pollutants incurred by industry to meet BPT relative to no treatment (i.e., RWL to current LTA). The ratio of the first cost to the second cost is the measure of the BCT technology's cost effectiveness.

The next step in the BCT cost test is to compare the two tests' results (or ratios) to the POTW and industry benchmarks. As explained above, the ratios calculated for the BCT cost test must be less than the POTW and industry benchmarks, respectively, to pass the BCT cost test. For a more detailed explanation of the benchmarks, refer to the 1986 notice of final regulation for the BCT methodology. In this analysis, the benchmarks are as defined in that notice, but indexed to comparable year data as the costs of treatment. As at proposal, EPA has indexed all costs to 4th quarter 1991 dollars.

Finally, the costs and pollutant removals for each mill were apportioned according to subcategory production. Baseline (RWL to current LTA) costs and pollutant removals are apportioned because mills are meeting their current limits based on all production at the facility, not just BPK and PS production. BCT option costs and pollutant removals are apportioned because the mill LTAs are calculated using proposed LTAs for **all** subcategories, not just the new LTAs for the BPK and PS subcategories. Mill LTAs for each option were calculated by multiplying the mill's percent production for each subcategory by the subcategory proposed LTA and then summing. Therefore, the calculations for both baseline and BCT option costs and pollutant removals are:

$$\text{Costs} = \text{Total annualized cost} \times \text{percent production in BPK (or PS)}$$

$$\text{Removals} = \text{Total pollutant removals (BOD}_5 + \text{TSS)} \times \text{percent production in BPK (or PS)}$$

12.4.4.3   Cost Test Results

The final BCT cost test results for the Bleached Papergrade Kraft and Soda and the Papergrade Sulfite Subcategories are shown in Table 12-3. None of the candidate technology options passed the BCT cost test. Therefore, EPA is not promulgating more stringent BCT effluent limitations guidelines for Subparts B and E at this time. Rather, the BCT limitations promulgated for former Subparts G, H, I, and P (now Subpart B) and former Subparts J and U (now Subpart E) remain in effect.

12.5   <u>References</u>

1.   Means. <u>Building Construction Cost Data</u>. 54th Annual Edition, 1996.

Table 12-1

Best Conventional Pollutant Control Technology (BCT) Costs

Subcategory[1]	BCT Option	Capital ($)	Engineering O&M ($/yr)	Total Annualized Costs (1995 $)
Bleached Papergrade Kraft and Soda	Option 1 (best 90%)	102,006,505	12,059,708	17,181,639
	Option 2 (best 50%)	172,405,961	18,724,362	28,092,172
Papergrade Sulfite	Option 1 (average)	11,030,865	593,202	1,451,886

[1]Costs for mills with operations in more than one subcategory have been apportioned based upon annual production.

12-11

Table 12-2

Conventional Pollutant Reductions Associated With BCT

Subcategory[1]	BCT Option	BOD$_5$ Reductions (lb/yr)	TSS Reductions (lb/yr)
Bleached Papergrade Kraft and Soda	Option 1 (best 90%)	47,108,171	73,738,529
	Option 2 (best 50%)	74,873,613	118,476,733
Papergrade Sulfite	Option 1 (average)	3,115,156	4,065,428

Table 12-3

Results of the Final BCT Cost Test

	Bleached Papergrade Kraft and Soda - Option 2 (best 50%)	Bleached Papergrade Kraft and Soda - Option 1 (best 90%)	Papergrade Sulfite - Option 1 (average)
A. POTW Test			
Total Annualized BCT Costs (1995 $)	$28,092,172	$17,181,639	$1,451,886
Pounds Removed by BCT	193,350,346	120,846,700	7,180,583
Industry BCT Benchmark (cost per pound removed relative to current LTA)	0.15	0.14	0.20
POTW Benchmark (cost per pound to upgrade to advanced secondary treatment)	0.48	0.48	0.48
Is BCT cost < POTW cost?	YES	YES	YES
Pass/Fail Test	PASS	PASS	PASS
B. Industry Cost Test			
RATIO 1			
Total Annualized Costs (RWL to Current LTA)	$241,694,766	$241,694,766	$19,439,167
Pounds Removed (RWL to Current LTA)	3,375,724,754	3,375,724,754	277,287,784
B1. Industry BCT Cost (from Part A)	0.15	0.14	0.20
B2. Industry Current Cost (RWL to Current LTA)	0.07	0.07	0.07
RATIO1: Ratio of B1 to B2	2.03	1.99	2.88
RATIO 2			
C1. POTW Benchmark	0.48	0.48	0.48
C2. POTW Cost to upgrade from no treatment to secondary	0.37	0.37	0.37
RATIO2: Ratio of C1 to C2	1.29	1.29	1.29
Is Ratio 1 < Ratio 2?	NO	NO	NO
Pass/Fail Test	FAIL	FAIL	FAIL

SECTION 13

ABBREVIATIONS AND CONVERSIONS

13.1   Abbreviations

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran
ACM	active chlorine multiple
AF&PA	American Forest and Paper Association
AOX	Adsorbable organic halides. A bulk parameter which measures the total chlorinated organic matter in wastewater.
ASB	aerated stabilization basin
AST	activated sludge treatment
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BID	Background Information Document: Pulp, Paper, and Paperboard Industry--Background Information for Proposed Air Emission Standards (October, 1993)
BFR	bleach filtrate recycle
BLS	black liquor solids
BMP	Best Management Practices
BOD_5	Five-day biochemical oxygen demand
BPK	bleached papergrade kraft and soda mills
BPT	Best Practicable Control Technology
C	bleach sequence symbol for chlorine stage
CAA	Clean Air Act
CBI	confidential business information
CDD	chlorinated dibenzo-p-dioxin
CDF	chlorinated dibenzofuran
CEK	target kappa number
CEM	continuous emission monitor
CFR	Code of Federal Regulations

ClO_2	chlorine dioxide
CMN	corrugated, molded and newsprint
CO_2	carbon dioxide
COD	chemical oxygen demand
CTMP	chemi-thermo-mechanical pulp
CWA	Clean Water Act
D	bleach sequence symbol for chlorine dioxide stage
DBD	dibenzo-p-dioxin
DBF	dibenzofuran
DCN	document control number
E	bleach sequence symbol for extraction stage
EA	Economic Analysis for the National Emission Standards for Hazardous Air Pollutants for Source Category: Pulp and Paper Production; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category - Phase I, Record Section 30.5, DCN 14649.
EAD	Engineering and Analysis Division
EC	extended cooking
ECF	elemental chlorine-free
EMCC®	extended modified continuous cooking, a registered trademark of Kamyr, Inc.
EPA	U.S. Environmental Protection Agency
FR	Federal Register
GAC	general and administrative costs
H	bleach sequence symbol for hypochlorite stage
HAP	hazardous air pollutant
HVLC	high concentration low volume
HW	hardwood
ISO	International Organization for Standardization
ITC®	Iso Thermal Cooking, a registered trademark of Kvaerner

LTA	long-term average
LTS	long-term study
MACT	Maximum Achievable Control Technology
MCC®	Modified Continuous Cooking, a registered trademark of Kamyr, Inc.
ML	minimum level
N	bleach sequence symbol indicating the absence of a washing stage
NA	not applicable
Na$_2$SO$_4$	sodium sulfate
NAICS	North American Industry Classification System
NC	not costed
NC	not counted
NCASI	National Council of the Paper Industry for Air and Stream Improvement, Inc.
ND	not detected
ND	not disclosed to prevent compromising confidential business information
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
NSPS	New Source Performance Standards
O	bleach sequence symbol for oxygen stage
O&M	operating and maintenance
OAR	Office of Air and Radiation
OD	oxygen delignification
P	bleach sequence symbol for peroxide stage
PCS	permit compliance system
pH	negative logarithm of the effective hydrogen-ion concentration in moles per liter, a measure of acidity
PMP	pollutant minimization program

POTW	publicly owned treatment works
PS	papergrade sulfite mills
PSES	Pretreatment Standards for Existing Sources
PSNS	Pretreatment Standards for New Sources
Q	bleach sequence symbol for acid chelant stage
QA	quality assurance
QC	quality control
RDH®	Rapid-Displacement Heating, a registered trademark of Beloit Corp.
RWL	raw waste load
S	bleach sequence symbol for sodium bisulfite
SCC	Sample Control Center
SIC	Standard Industrial Classification
STDD	Supplemental Technical Development Document for Effluent Limitations Guidelines and Standards, for the Pulp, Paper, and Paperboard Category Subpart B (Bleached Papergrade Kraft and Soda) and Subpart E (Papergrade Sulfite), October 1997
STFI	Swedish Forest Products Research Institute
SW	softwood
TCF	totally chlorine-free
TDD	Technical Development Document for Proposed Effluent Limitations Guidelines and Standards for the Pulp, Paper, and Paperboard Point Source Category, October 1993
TEQ	toxic equivalent
TRS	total reduced sulfur
TSS	total suspended solids
UBK	unbleached kraft mills
Z	bleach sequence symbol for ozone stage

13.2 <u>Units of Measure</u>

ADMT	air dry metric ton
ADT	air dry (short) ton
atm	atmosphere
bbl	barrel
BTU	British Thermal Unit
d	day
g	gram
G	giga
kg	kilogram
kkg	1,000 kilograms = 1 metric ton = 1 mega gram
kPa	kilopascal
kWh	kilo Watt hour
J	joule
L	liter
m^3	cubic meter
mg	milligram
M	mega
MGD	million gallons per day
ng	nanogram
OMMT	off-machine metric ton
OMT	off-machine (short) ton
pg	picogram
ppb	part per billion
ppm	part per million
ppq	part per quadrillion
ppt	part per trillion
psi	pounds per square inch
	microgram

UBADt   unbleached air dry ton

UBMt   unbleached metric ton

W   watt

yr   year

13.3   <u>**Unit Conversions**</u>

Table 13-1 presents mass and concentration unit conversions used throughout this document.

Table 13-1

Units of Measurement

Mass Units		
Unit	**Unit Abbreviation**	**Equivalent Mass in Grams**
Gigagram	Gg	1,000,000,0000
Megagram or Metric ton	Mg or kkg	1,000,000
Kilogram	kg	1,000
Gram	g	1
Milligram	mg	0.001
Microgram		0.000001
Nanogram	ng	0.000000001
Picogram	pg	0.000000000001
Femtogram	fg	0.000000000000001
Concentration Units		
Unit Abbreviation	**Liquids**	**Solids**
ppm (10^{-6})	mg/L	mg/kg =
ppb (10^{-9})		
ppt (10^{-12})	ng/L	ng/kg = pg/g
ppq (10^{-15})	pg/L	pg/kg = fg/g

Notes: (1)   For liquids, conversions from metric concentration unit to ppm, ppb, ppt, and ppq are approximate.

(2)   1.0 kg = 2.2046 lbs.

Source: American Petroleum Institute
Publication No. 4506, March 1990